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The "R-34," at Mineola, Long Island, July 8-9, 1919. The first dirigible to make the round trip across the Atlantic

Progress In Naval Aircraft—I*

Contributions to Naval Aircraft-Design and Construction by the United States, Culminating in the "NC-4" Type

By Commander J. C. Hunsaker, Bureau of Construction and Repair, U. S. N.

WITH aircraft, as with battleships, destroyers and all men-of-war, the types used by the United States Navy have come to be known as distinctively American types, although the military problem solved by each type is usually not distinctively American. This result has to a large extent come about through a natural American prejudice against copying features of design and construction with which we are inexperienced. This prejudice is, of course, a stimulant to originality, but must be tempered by good judgment or good engineering, which is the same thing. A constructor, while he should very properly hesitate to copy practices he only half comprehends, must at the same time be quick to recognize the merits of a foreign development and to adapt or adopt its good features in his own work.

During the war the Navy selected only one foreign seaplane type to be copied in the United States. This was the British Admiralty's flying boat, F-5, plans of which were brought to the Naval Aircraft Factory early in 1918 when the factory was going in full production on the H-16 flying boat, a Curtiss development. Production was shifted over to the new model with considerable trouble and delay because it had a superior bomb capacity and air endurance. But as soon as a start was made to prepare the necessary production data for the factory and its subcontractors, it was realized that very material changes would have to be made. In fact, before the boat was finally got into production it resembled the British prototype only in externals. The changes made can be classified under these heads:

(1) Change of powerplant installation from Rolls-Royce to Liberty, involving new oil, water and gasoline systems and starting arrangements.

(2) Change of design of all metal parts and fittings to permit use of American practice in metal stamping machinery and to eliminate hand work.

(3) Change of design of all pins, nuts and bolts to American standards.

(4) Change of controls in boat from single to dual to meet demands of American flyers.

(5) Change from unbalanced to balanced allerons to ease up load on the pilot.

(6) Change of bomb racks and gear for American equipment.

(7) Change of internal hull construction from British practice with ribs to American practice with longitudinal stringers.

(8) Substitute laminated struts and wing spars for solid types to save spruce.

(9) Change bottom planking and step construction to American practice.

(10) Change system of covering wings to American practice, using cotton instead of linen.

(11) Strengthen tail where it appeared weak.

(12) Remake all plans to permit quantity production of interchangeable parts assembled from a multitude of subcontractors.

The American theory of manufacture is to assemble parts procured from separate makers or departments if all are made in the same plant. To apply this theory of manufacture the design has to be prepared accordingly. Also we have American practices, standards and special materials to be looked out for. Some of these special practices and materials are common to both Army and Navy and represent industrial development, but a great many are peculiar to the Navy alone and have been arrived at as the result of experience or research.

The Navy with aircraft, as with ships, does the greater part of its own designing and building through its Corps of Naval Constructors. At the same time, private design and construction are encouraged by contracts with builders which lodge engineering control in the Navy Department.

The NC flying boats, whose very recent transatlantic performance is too well known to be gone into here, represent a typical example of how the Navy operates on the engineering side. Their design and construction made use of available talent both in and out of the service, the facilities of parts makers and the new materials developed during the war, and, in general, represent the result of organized engineering rather than invention. For this reason no one man can be said to have designed these craft, although the Chief Constructor of the Navy, Admiral Taylor, was at all times responsible for ways and means and results as well as the initial conception of the project.

The NC flying boat is, as I say, typical of Naval practice, and in describing it I can give some idea why it is a distinctively American type and some account which may be interesting to engineers of any new processes and materials used.

In the same way the airship or Dirigible C-5 is a distinctively American type, and while I regret that we did not succeed in crossing the Atlantic with it, the flight from Long Island to Newfoundland proved the possibilities from an engineer's point of view. It appears certain that had we set out with three airships, as we did with three flying boats, to make the "big hop across," at least one would have made it. The design and construction of the C class airships made use of organized engineering, just as did the NC project, and in describing it I could cover the wartime development in airship construction of the Navy. However, to do so would make this paper too long and I shall confine myself to heavier-than-air craft.

The development of really large flying craft before 1917 was held back because no suitable engine had been designed. Several attempts, both at home and abroad, had resulted in failure, notably the Curtiss giant triplane and the Sikorski, both land machines. When the 350-hp. Rolls-Royce became available, the four-engine Handley-Page was brought out in England, but in the United States no American engine was in sight until about August, 1917, when the preliminary work on the Liberty began to look promising.

Admiral Taylor, as a member of the Aircraft Board, was in a position to weigh the evidence as it came in and to foresee the ultimate success of the new engine. This engine, then known as the "United States Motor," was still under a cloud of unfavorable comment from foreign and domestic experts, but the early troubles were recognized as natural and inevitable and the chance of success looked good.

About this time the German submarines were extremely active and successful and there were grave doubts of there being shipping available to transport to Europe the great tonnage of American material necessary to prosecute the war. In particular, one of the weapons needed to keep down the submarine was the flying boat, and unless we had a great number of flying boats on patrol over the European submarine-infested areas the shipping space available would be rapidly diminished, and unless there was shipping space the flying boats could not get over. It was a vicious circle and could be broken only by flying the boats across the Atlantic under their own power. For 1918 we had a large program of flying boats which were indeed large, but not quite large enough to be flown safely across the Atlantic. In 1919 we needed something bigger, and to prepare for quantity production, the experimental models would have to be brought out in 1918.

THE BEGINNING OF THE NC BOATS.

The first step to provide the transatlantic boats was the following memorandum:

WASHINGTON, D. C., Aug. 25, 1917.

From D. W. Taylor, Chief Constructor, U. S. N.
To J. C. Hunsaker, Naval Constructor, U. S. N.

The "United States Motor" gives good promise of being a success, and if we can push ahead on the aeroplane end, it seems to me the submarine menace could be abated, even if not destroyed, from the air. The ideal solution would be big flying boats or the equivalent, that would be able to keep the sea (not air) in any weather and also able to fly across the Atlantic to avoid difficulties of delivery, etc.

Please think it over very carefully, particularly as to the method of procedure to develop something as close to the ideal as possible.

Design studies were at once put in hand and from time to time various men were called in consultation with the regular design staff of the Bureau of Construction and Repair. Ideas and suggestions from all sources were considered, and the design itself became a composite of ideas, these being chosen and incorporated into the design on the basis of suitability and merit and without any reference to their source.

Plans were then prepared in the Bureau for a boat of this character to be fitted with three engines and for one to be fitted with five engines. The predicted performance was computed for each boat from which it appeared that the three-engine boat could be made to satisfy the general requirements of the problem and could be built much more quickly and with smaller risk of failure. Admiral Taylor accordingly directed that the design staff of the Bureau be put on the plans of the three-engine type. Investigations were at once undertaken to determine in a preliminary way the construction of wing beams, struts and the principal structural members, the proportions of wing area, fin and control surface areas and the materials to be employed for important parts. The general appearance of the design was worked out and the procedure to be followed in making the detail drawings established.

A 3-ft. model of the design was then made exactly to scale and tested by Dr. A. F. Zahm in the wind tunnel of the Washington Navy Yard. From his investigations of the forces of this model when held in a 70-mile per hour artificial wind, the size and arrangement of tail surfaces needed to guarantee stability and correct balance in flight were determined. With a machine of the unprecedented size contemplated, it was vitally necessary that there should be no doubt on this score, as an accident on the trial flights would set the project back many months besides risking the lives of the crew.

The design being worked upon was of dimensions far beyond any previous experience in this country, indicating that much unfamiliar territory would have to be covered. New methods of construction would be required that the design might be successful, as, otherwise the weight of the design would increase with such rapidity as to make success impracticable. In the state of design information as it existed in the United States on that date, this necessity was one of the greatest seriousness and one which imposed upon the personnel connected with the design a great amount of investigation and experimentation in the working out of the details referred to.

It soon became apparent that the carrying on to the completion of design work of such dimensions at the Bureau of Construction and Repair in Washington would be impracticable, unless the entire facilities of that Bureau were devoted to this work. Under the enormous pressure of air matters connected with the war which had devolved upon this Bureau, in common with the other bureaus of the Navy Department, this was impossible and it was accordingly decided to arrange with a private company of Buffalo, N. Y., to complete the drawings with their own design facilities, and with the contribution by themselves of such ideas of value as might develop under the control and supervision of the Bureau.

COMPLETION OF DESIGN BY OUTSIDE ORGANIZATION.

A contract was, therefore, made with a private corporation for the performance of this, the drafting and design work. Under the terms of this contract it was to carry out all work directed by the Navy Department, furnishing in connection therewith all facilities necessary. The Bureau of Construction and Repair reserved to itself the direction and oversight of all work coming under that Bureau and, for this purpose, placed in charge, as its field representative, Naval Constructor G. C. Westervelt. Active work on the detail design was begun at Buffalo early in October. Shortly after the commencement, Naval Constructor H. C. Richardson was ordered for duty in connection with the design of the hull.

In carrying on the actual work of design, the design as a whole was first divided into its main elements. These main elements were designed or approved by the Bureau of Construction and Repair and the various details of these were then distributed to the members of the design force at Buffalo working upon them. All ideas were pooled, and as details were worked out the decision to accept them was made as a result of discussion.

The flying boats were designated NC, N for Navy and C for the corporation, indicating the joint production of the Navy and the corporation. Being designed for war service, the boats are not at all freak machines put together to perform the single feat of a record-breaking flight but are rugged and comfortable craft designed and built in accordance with standard Navy practice. The NC-1 was in service 7 months and

*Reprinted from *Jour. Soc. Automotive Engineers.*

had rough handling when the new pilots for the other NC boats were trained on her but was in good condition to start for the Azores and, considered all round, was the best boat of the four.

The term flying boat is used for the NC type because it is actually a stout seaworthy boat that ploughs through rough water up to a speed of 60 miles per hr. and then takes to the air and flies at a speed of over 90 miles per hr.

The hull or boat proper is 45 ft. long by 10 ft. beam. The bottom is a double-plank V with a single step somewhat similar in form to the standard Navy pontoon for smaller seaplanes. Five bulkheads divide the hull into six watertight compartments with watertight doors and a wing passage for access. The forward compartment has a cockpit for the lookout and navigator. In the next one are seated side by side the principal pilot or aviator, and his assistant. Next comes a compartment for the members of the crew off watch to rest or sleep. Aft of this there are two compartments containing the gasoline tanks where a mechanician is in attendance and finally a space for the radio man and his apparatus. The minimum crew consists of five men, but normally a relief crew would be carried in addition.

The hull is designed to have an easy flaring bow so that it can be driven through a seaway to get up the speed necessary to take the air and a strong V-bottom to cushion the shock of landing on the water. The combination of great strength to stand rough water with the light weight required of anything that flies was a delicate compromise, and it is believed that a remarkable result has been obtained in this design. The bare hull, as completed by the yacht builder and ready for the installation of equipment, weighs only 2,800 lb., yet the displacement is 28,000 lb., or 0.1 lb. of boat per lb. of displacement. This lightness of construction was attained by a careful selection and distribution of materials. The keel is of Sitka spruce, as is the planking. Longitudinal strength is given by two girders of spruce braced with steel wire. To guarantee watertightness and yet keep the planking thin, there is a layer of muslin set in marine glue between the two plies of planking.

The lines of the hull mark an important advance in the design of planing bottoms. In the early flying boats it was considered necessary to have great width to make the boat plane at reasonably low speeds. A usual rule has been to allow not over 100 lb. of displacement per in. of width. Sometimes, to get more width of bottom, side fins or pontoons were built out from the main hull, as in the F-5, H-16 and HS-1. In the NC hull the radical step was made of getting planing by speed rather than by width. The NC boats at the start from Newfoundland got off with a 233-lb. load per in. of width of planing bottom. This is possible because of the easy lines of the after body which permit a speed on the water up to 65 miles per hr. when all engines run at full speed. Running at this rate, it is very important that the pilot have control of the fore-and-aft attitude of the boat. This he can do by rocking the boat with his elevators. To permit such rocking while planing at high speed is a rather delicate design problem. With a two or more step hydroplaning bottom, the boat planes on at least two steps and hence is fixed in attitude so that there is nothing the pilot can do to change it. With a single deep step the boat gets up on this step and is quite unstable except for the air controls. Unless the pilot is expert he may get into difficulties, especially in a swell. The NC hull has a short distance back of the center of gravity a single deep step on which the boat can be rocked by the pilot after he gets up to planing speeds, but until sufficient speed is established to make the air controls effective, the stern of the boat is also planing on the water and acts somewhat as a second step to hold the boat in a reasonable attitude. The form of this stern is novel and constitutes an important improvement in the design of flying boats.

The tests of the model hull in the towing basin at the Washington Navy Yard showed that the boat got up to speed quickly if trimmed about 8 deg. by the stern. In practice the pilots have verified this "optimum trim" and at the start let the boat run at this designed or natural trim until it rises to the surface of the water and begins to plane. The trim is then reduced to 6 deg. to lessen the air resistance of the wings and keep down the lift so that the boat will stay on the water until the air speed meter indicates that flying speed is attained. When this rate is reached the pilot watches the sea and "waiting for a smooth time" pulls back the elevator column to increase the angle of incidence of his wings to about 15 deg., or a trim of boat of about 12 deg., to lift himself into the air. A feature of the NC hull is the ability to be pulled back in this manner and to keep on the water without "porpoising" until adequate speed is reached. Once in the air, it is necessary to stay there and not bounce back on the sea, subjecting the boat to abnormal shocks. Due to the pointed form of stern, when the pilot pulls up his elevators the point of the stern is pressed down into the water, thus increasing the trim.

THE NC HULL A TYPICAL AMERICAN CONSTRUCTION.

The NC hull construction is peculiar to American Naval practice from the use of a longitudinal framing system developed from experience with pontoons for seaplanes. The boat is divided into watertight compartments by transverse strength bulkheads of two-ply planking riveted together over a layer of cotton fabric set in marine glue. This construction had been found to be light, strong and to retain watertightness even when distorted or strained due to the peculiar property of the marine glue of remaining soft and sticky. Such planking is our practice for bulkheads, inner and outer skins of boat hulls and wherever watertightness is desired.

The object of the glue and fabric is to provide a water-proof film that will remain permanently flexible and sticky and at the same time seal up the holes made in the planking when the two layers are fastened together with innumerable brass or copper tacks. It was found soon after hostilities began that the type of marine glue which had previously been used for this purpose was almost unobtainable, since it was all made abroad. The American production of this product was necessary and the Bureau of Construction and Repair established certain standards or requirements which have been successfully met by American manufacturers. The requirements of a satisfactory glue are many; for instance, it should be of a non-drying nature and must remain perfectly soft, flexible and sticky. If it contains too large a quantity of volatile solvent rapid drying will be effected and hardening of the glue will result, with consequent separation of the layer of planking. It must also be resistant to salt water and must not foam up and exude between the plies when subjected to long-time immersion. After the glue is applied a short time is allowed before the hull is painted. The varnish and enamel is then applied. Marine glues are usually composed of a mineral gum, shellac, pine tar, cellulose lacquer or rubber dissolved in the necessary solvents to the consistency of molasses.

The tail in the NC is unique and resembles no other flying machine or animal. The tail surfaces are made up as a biplane which resembles in general appearance and size the usual airplane. Indeed, this tail of over 500 sq. ft. area is twice as large as the single-seater fighting airplanes used by the Army. This tail structure is supported by three hollow spruce booms braced by steel cable in such a way as to remain clear of all breaking seas and to permit a machine gun to be fired straight aft from the stern compartment without interference. The method of support is a radical change from former American and foreign practice but has resulted in several advantages besides an important saving in weight.

The tail surfaces were proportioned after extensive wind-tunnel tests at the Washington Navy Yard and the area and settings adjusted to give correct flying balance and inherent longitudinal stability. The horizontal stabilizers are inclined 1 deg. to the chord of the wings. This angle has been found on trial to give a very easy balance, and running along at normal speed the boat practically flys herself in good air, requiring no work by the pilot. Naturally, in bumpy air the pilot has something to do, but due to the great inertia, bumps which would toss an ordinary machine about are barely felt. The boat is inherently stable to such a degree that if disturbed from normal flying attitude by any cause it will return to it without the intervention of the pilot. At the same time the controls are powerful enough to overcome the inherent stability so that the pilot is able to handle the boat in the usual manner. Naturally, in a boat of such size, quick maneuvering is not possible, and for this reason the usual factors of safety were cut down in a most radical manner. The results have justified the conclusions arrived at as to factors of safety based on purely theoretical considerations.

To insure easy operation, each control surface was carefully balanced in accordance with experiments made in the wind tunnel on a model of it. The operating cables were run through ball bearing pulleys and all avoidable friction eliminated. Finally, the entire craft was balanced so that the center of gravity of all weights came at the resultant center of lift of all lifting surfaces. There is provision, however, for an assistant to the pilot to relieve him in rough air if he becomes fatigued or wishes to leave his post to move about the boat. The matter of providing a servo-motor was at first thought worth going into, but on trials the controls were found to be so easy as to make it unnecessary to provide for power operation. A British type of servo-motor had, however, been imported and fifty units made and issued to the service for trial. Some of the twin-engine boats have been found heavier on controls than the NC and good results have been had using servo-motors on them.

The standard Navy practice is to design tail surfaces for a load of 20 lb. per sq. ft., but on the NC the horizontal stabilizer is designed to fail under a load of 13.5 lb. per sq. ft. The vertical fins are designed for 7 lb. per sq. ft. load and the rudders and movable surfaces for 10 lb. The main wing girder when loaded to 28,000 lb., the maximum permissible overload for start of the transatlantic flight, has a general factor of safety of 3, as against 6 for ordinary seaplanes and 8 to 12 for pursuit land types. No evidence of structural weakness has developed so far, but of course in designing for such low factors of safety the greatest care has been taken in the selection of material and the structural calculations.

THE USE OF SPRUCE PARTS.

In the last few years we have learned considerable about the mechanical properties of spruce and now use it with confidence where before we employed it only after prayerful consideration and the allowance of a very liberal factor of safety. In the NC spruce was used wherever possible for tail booms, wing spars, ribs, struts and internal hull work and wherever bending was unnecessary.

The knowledge of the mechanical properties of spruce which we now have and which enables us to use straight engineering calculations, is due principally to three things: First, the research data of the Forest Products Laboratory; second, the experience of our own inspectors and builders in selecting sound and uniform timber; and third, the knowledge gained by experience which enables us to employ the wood in laminated and spliced form.

In the study of the effect of moisture content of wood it was found necessary to season it artificially in a dry kiln and to run the seasoning process as carefully as the heat treatment of steel. The wood when seasoned should be sealed up at once by varnish to prevent warping and checking. In our usual quantity manufacturing method, wood parts cannot be used at once and must be kept in stock a rather indefinite period before they are wanted in the assembly operation. It is not practicable to varnish many parts before assembly, especially where glue is to be used. A solution of the difficulty was found at the Naval Aircraft Factory, where humidity control of the air of the entire plant was incorporated in the heating and ventilating system. Such a system has been used in cotton mills but is believed to be new in a wood-working or aircraft factory. The results have been most successful and fully justified the additional outlay. Wood parts cut to fit can be stored in the shop for a considerable period of time and when finally assembled go together perfectly.

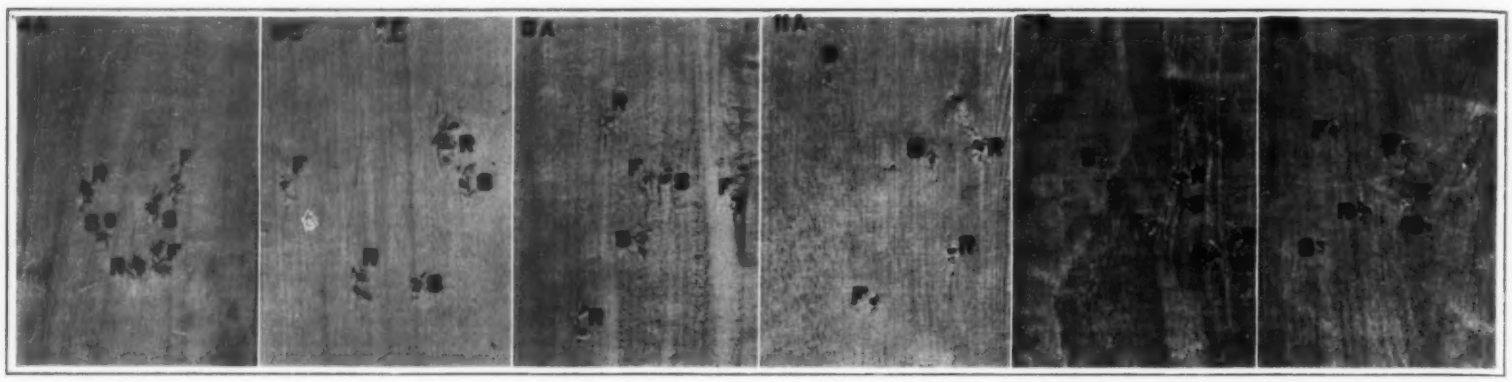
The work of the Forest Products Laboratory has swept away the mystery which formerly surrounded attempts to use wood as a material of engineering construction. The relation between the density, moisture content and strength of the wood is now understood. The usual defects such as pin knots, spiral grain, etc., have been analyzed and their effects taken account of in establishing tolerance tables for any given design of plane. Naturally, for the NC where the factor of safety had been reduced to a minimum it was necessary to use absolutely clear, straight stock of correct density. To insure faultless material it is much easier to use laminated and spliced work where more thorough inspection of each part can be given.

The wings are of a curvature known from experience to be efficient, designated as R. A. F. 6, and carry a load of 11.7 lb. per sq. ft. in the air, but the structural weight is only 1.2 lb. per sq. ft. The total area is 2,380 sq. ft. Wings of this size could not be constructed by the usual methods and materials without exceeding this figure considerably and a great amount of research and experiment has been necessary to determine the best disposition of material to adopt.

The main wing spars are hollow spruce boxes. Each rib is a truss designed like a bridge consisting of continuous cap strips of spruce, corresponding to the upper and lower chords of a bridge truss, tied together by an internal web system of vertical or diagonal pieces of spruce.[1] The ribs are 12 ft. long but only weigh 26 oz.

(*Continued on page 76*)

[1]Detail illustrations of the construction of these parts will be found in the issue of the SCIENTIFIC AMERICAN for June 7, 1919, pp. 604—605.



Tanguile Yellow Birch Prima Vera White Pine High Density—African Mahogany—Low Density

Fig. 1—Typical Panels after test.—Line of fire: perpendicular to grain (S); at 45° with the grain (F); at 45° across the grain (R).

Splintering of Airplane Woods

Actual Tests of Different Available Airplane Woods to Determine Relative Splintering Under Rifle Fire

By G. E. Heck, Engineer, Forest Products Laboratory, Madison, Wis.

THE importance of determining which airplane woods will offer the greatest resistance to splintering under rifle or machine-gun fire can readily be realized when one stops to consider the shower of bullets to which a battle plane is often subjected in an engagement. Other things being equal, an airplane or propeller built of wood which shatters or splinters badly, will not give as good service as one built of wood which shows a relatively small, clean-cut hole when struck by a bullet.

The determination of the relative resistance to splintering under rifle fire of some of the most common airplane woods was one of the problems submitted by the War and Navy Departments to the U. S. Forest Products Laboratory, Madison, Wis., for investigation during the war.

The laboratory investigation covered the ten species of wood shown in Table 1, which gives the moisture content and specific gravity of the test panels.

Three panels 15/16 inch by 8 inches by 16 inches of each species were tested, except in the case of the mahoganies, for which four panels were used, two of high-density and two of low-density material.

Fig. 3.—Bullet holes, showing small splinters and no splitting

Model 1898 United States Army rifles shooting .30-calibre, 220-grain, steel-jacketed ball cartridges with an initial velocity of 2,000 feet per second were used in the test.

METHOD OF TESTING.

In the first series of tests the panels were placed perpendicular to the line of fire, each panel presenting a target 8 inches wide by 16 inches high. Two bullets were fired through each panel from a range of about 35 yards, and the results of these shots are marked "S" on the photographs.

The second series of tests was similar to the first, except that the panels were inclined 45° to the horizontal plane. The results of these shots are marked "F."

The third series was made with the panels hung vertically, as in the first instance, but revolved 45° about a vertical axis. The results of these shots are marked "R."

Thus there were three angles at which the bullets cut the grain of the wood—at right angles to the grain, 45° with the grain, and 45° across the grain.

The results may best be understood from an examination of the photographs. The splintering effect of the bullets on leaving the wood, in typical panels of each species, is shown in Figs. 1 and 2. Fig. 3 shows a bullet hole in a wood with no splitting and small splinters, and Fig. 4 shows one in a wood with considerable tendency to split and form long coarse splinters.

Results of moisture content and specific gravity determinations on test panels based on oven-dry weight and oven-dry volume are shown in Table 1.

Table 1. (*Average for Each Species Tested.*)

Species	Moisture Per cent.	Specific Gravity
Sitka spruce	10.5	0.41
Black walnut	12.6	0.58
Prima vera	13.3	0.47
Tanguile	15.3	0.59
White oak	15.0	0.69
Yellow birch	12.3	0.66
African mahogany: High density	11.0	0.56
Low density	10.5	0.42
Central American mahogany: High density	9.5	0.51
Low density	13.0	0.36
White pine	9.6	0.36
White ash	11.9	0.64

Observations show that the 10 species may be divided into two groups—one in which there was very little or no splitting, or in which the splinters formed were short and fibrous; and the other in which the wood showed a decided tendency to split, or in which relatively long coarse splinters were formed.

The two groups are as follows:

Group 1	Group 2
Woods with no Splitting Tendency:	Woods with Decided Splitting Tendency:
Tanguile	Black walnut
Yellow birch	Sitka spruce
Prima vera	White oak
White pine	White ash
African mahogany	
Central American mahogany	

A tendency of the wood to crack or split is indicated on the photographs by a dash under the letter designating the bullet hole.

There was apparently very little difference in the splintering effect due to the change in the angle at which the bullet entered the wood. All the panels had holes of irregular outline, and splinters of various sizes formed on the back surface where the bullets pierced the wood.

The African mahogany panels seemed to offer a greater resistance to splitting than the white oak. The splinters of the latter species were long and coarse, while those of the former were short and fibrous.

There was no apparent difference in the relative resistance to splintering between high and low-density mahogany. No comparison was made between high and low-density specimens of the other species.

Although black walnut was placed in Group 2 on account of the tendency to split, the splinters formed were small and the bullet holes were not so large as those of the other species in this group.

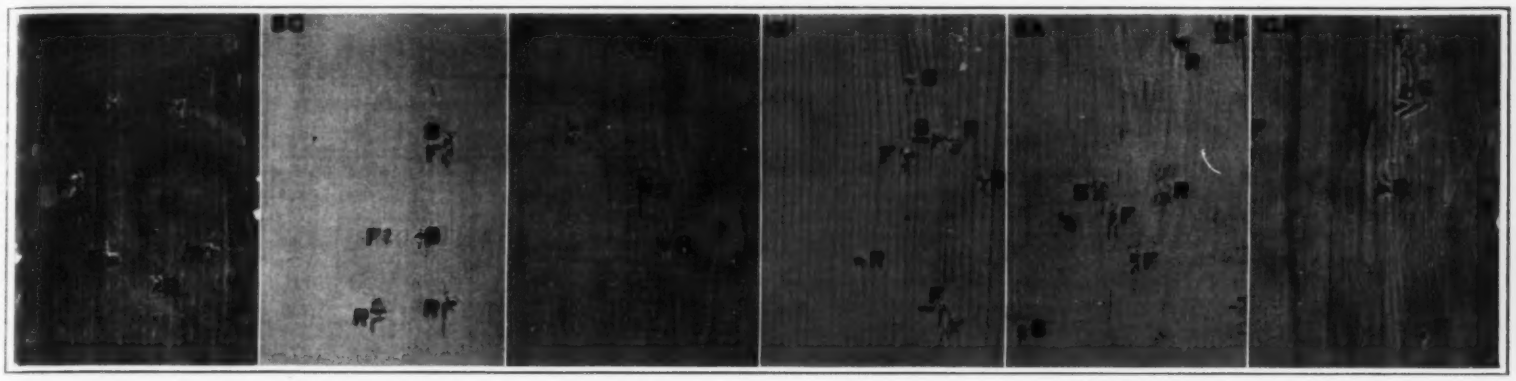
White ash seemed to split the worst and forms large splinters. The largest holes were made in the panels of Sitka spruce although this species did not seem to split so badly as white oak and white ash.

Compression Strength of Glass and Quartz

EXPERIMENTS were made in the optical works of C. P. Goerz with an Amser machine, first on cubes, up to 15 mm. side length, and then on cylinders, 5 mm. in diam. and height, placed between steel plates which were attacked by the quartz. The specimens were either all polished or only finely ground; although the possible lesion of the surface by the grinding did not appear to make any difference in the strength, it is recommended that for all glass-testing only specimens prepared as for optical work should be used. The specimens frequently split before rupture took place with almost explosive violence. The strength decreased from 13,000 kg./cm.² to 8,800 kg./cm.² as the cube size increased from 5 to 15 mm. in the case of mirror glass. The boro-silicate crown glass of the

Fig. 4.—Bullet hole, showing large splinters and tendency to split

Sendlingen Optical Glass Works was especially tested, either most carefully cooled or rapidly cooled in air from 600° C. downward, and very badly strained therefore. The strained material gave more regular and higher strength values (18,400 kg./cm.² max., 15,000 kg./cm.² average), than the strainless material (16,900 kg./cm² max., 14,200 kg./cm.² average), and these latter values further went down by about 7% (to 15,000 and 12,500) when the load was not put very gradually, but in steps of 100 or 200 kg., while the rate of applying the load had no influence in the former case. The quartz tests, also made on 5-mm. cylinders, yielded slightly higher values when the pressure was applied parallel to the optical axis than when at right angles to the axis, the maxima in the two cases being 28,000 and 27,400, the averages 25,000 and 22,000 kg./cm.² The quartz values are higher than those previously found by A. Winkelmann and O. Schott and by Rinne, but the glass values are lower.—G. BERNDT, in *Deut. Phys. Gesell.*



High Density—Central American Mahogany—Low Density Black Walnut Sitka Spruce White Oak White Ash

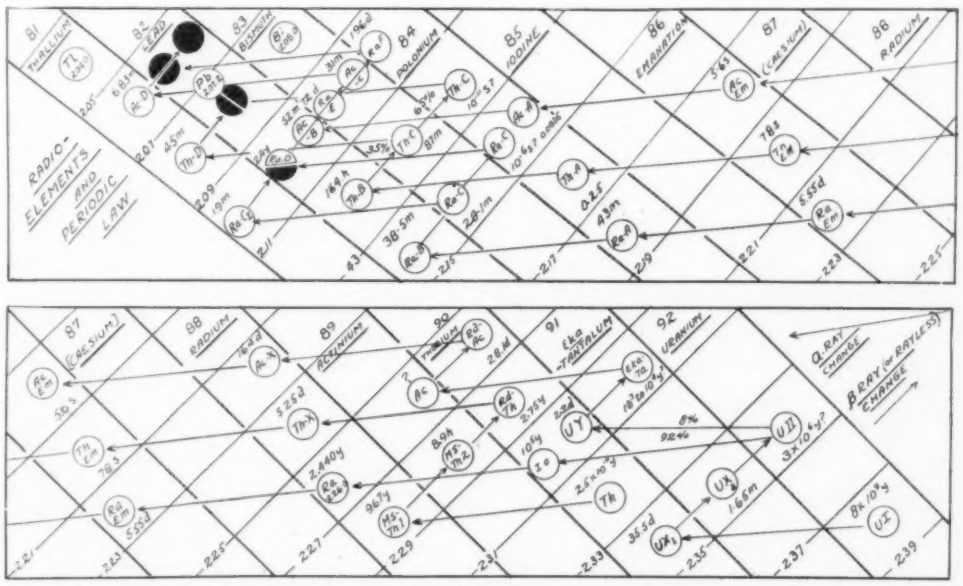
Fig. 2.—Typical panels after test.—Line of fire: perpendicular to grain (S); at 45° with the grain (F); at 45° across the grain (R.)

What Is a Chemical Element?*

Our Concept of the Chemical Element Modified by Study of Radio-Active Change

By Frederick Soddy, F.P.S.

If a chemist were to purify lead from silver, and found on re-examining the lead that silver were present, and if, again and again, silver, initially absent, reappeared the doctrine of the unchangeability of the elements would be at an end. The conclusion in 1902 by Sir Ernest Rutherford and myself with regard to the element thorium was of this direct and simple character. As often as the constituents responsible for the radio-activity are separated by physical or chemical means, they reform. One of the constituents, the thorium emanation, is a gas which was shown to possess the complete absence of chemical character characteristic of the argon family of gases. It is formed from thorium through the intermediary of another constituent, thorium-X, which is left in the filtrate, when a solution of thorium is precipitated by ammonia, but not by other chemical reagents. In turn the emanation changes into non-volatile products causing the active deposit. The clear conception of the nature of chemical change, the distinction between atoms and molecules, which we owe to the founders of chemistry, made it possible to recognize radio-active change almost instantly as a case of spontaneous transmutation. Novel as the explanation was, the phenomena explained are so novel as to transcend what to a generation ago would have appeared as the limits of the physically possible. But even today it is only in radio-active phenomena that the limits reached long ago in the chemical analysis of matter have been overstepped, and the rubicon, which many have vaulted over so lightly in imagination, has actually been crossed by science.



Prof. Soddy's diagram showing positions in the periodic table, and derivations of the radio-active elements

The first phase of the study of radio-active change was mainly concerned with the disentanglement of the long and involved sequence of transformations which, starting from uranium and thorium, were ultimately found to include all the known radio-elements. Beyond the fact that the radio-elements were in present course of evolution, it added little to the conceptions of chemistry. But in the second and more recent phase—concerned with the chemical character of the successive products, the law connecting this with the type of ray expelled in the change, the discovery of elements with unique radio-active but identical chemical and spectroscopic character, the identification of these as isotopes, or elements occupying the same place in the periodic table, the interpretation of the latter and the recognition that the so-called chemical elements are in reality heterotopes, or substances occupying different places in the periodic table, and are not necessarily even homogeneous—conclusions, not merely novel, but upsetting, have been reached.

The criterion at first relied upon in the analysis of matter into its elements, the possession of a unique chemical character, was added to by Dalton's atomic theory, which gave to each element a unique atomic weight. The periodic law apparently connected these two criteria, fitted the individual elements into families, and showed that, whatever the elements were, they were all of a class, the limits of chemical analysis, and, if complex, then all of the same kind of complexity. The periodic law introduced a third criterion of the element, that it occupied a place to itself in this scheme, and the discovery of spectrum analysis, a fourth, that it possessed a unique spectrum. The discovery of radio-activity introduced a fifth, the possession of a unique radio-active character, in the case of the radio-elements. Of the first three new elements discovered by the aid of the fifth criterion, polonium, actinium, and radium, the claim of the last to the title of element was brilliantly substantiated by the successive determination of its unique spectrum, unique chemical character, unique place in the periodic table, and unique atomic weight. The production of this element from uranium through the intermediary of ionium, and the production of helium from radium, and, in due course, from the other radio-elements, furnished conclusive proofs of the correctness of the first interpretation of the transmutational character of radio-active change.

Then came a totally new departure. The possession of unique radio-active character does not always, as in the case of radium, connote unique chemical and spectroscopic character. As, one after another, the various members of the disintegration series were distinguished, by their breaking up in characteristic ways at definite rates, no further *chemically new* elements were found. All resembled known elements so closely that they could not be separated by chemical analysis, and those actually at work on these substances came to the conclusion that the chemical resemblances amount to identity. Radio-thorium is, for example, identical chemically with thorium. It was isolated from thorium and individually recognized by Sir William Ramsay and O. Hahn only because it is formed from thorium through an intermediate product, mesothorium, chemically different from thorium, but chemically identical with radium. No more elegant addition, not merely to knowledge, but also to the means of winning knowledge, can be imagined. Two separate substances, radio-thorium and thorium, in the original analysis of the thorium disintegration series, taken for one, become individually knowable, because the first is formed from the second through a third substance chemically totally distinct from either. Radio-active change thus furnished a new means of analysis, for which, outside the radio-elements, there is as yet no equivalent.

Further work on the chemical character of the various members of the disintegration series, notably by Fleck, who showed that practically all were chemically identical either with some common element or other radio-element, in 1913 paved the way for the generalization independently arrived at by Russell, Fajans, and myself, which is brought up to date and illustrated by the accompanying figure. Each α-ray change was found to cause a shift of two places in the periodic table in one direction, and each β-ray change a shift of one place in the other, the first change being accompanied by a reduction of four units of atomic mass, a helium atom being expelled, and the second not involving a sensible loss of mass. Thus the successive places in the periodic table were first associated with unit variation of atomic charge, for the β-particle is the negative electron, and the α-particle a helium atom carrying two positive atomic charges. The elements with identical chemical character were found to occupy the same place in the periodic table, and were, therefore, termed isotopes. Conversely, the elements recognized by chemical and spectroscopic analysis may be termed heterotopes.

In the figure, which is to be read at 45°, the numbers at the head of each place—92 for uranium, and so on—are the atomic numbers, or number of the place in the complete list of places in the periodic table, as determined by Moseley, on the assumption that the atomic number of aluminum, the thirteenth element in the list, starting from hydrogen, is 13. The period of average life of each member is shown above or below its symbol, a "?" indicating that the period is indirectly estimated from the range of the α-ray expelled. The last member to be added, eka-tantalum or protoactinium, the direct parent of actinium in an α-ray change, was discovered this year independently by Cranston and myself, and by Hahn and Meitner. For this element, for actinium, and for polonium, but for none of the others, are the criteria of unique spectrum and chemical character, as found for radium, to be

(*Continued on page* 77)

*Summary in *Nature* of a lecture to the Chemical Society, London.

Pre-Paleolithic Man in England*

A Review of the Evidence Which Has Been Gathered to Show His Existence

By J. Reid Moir, F.R.A.I.

It has been my purpose in the three articles already published in *Science Progress*[1] to draw attention to some of the various forms of flaked flints found in deposits of a greater antiquity than those containing the normal paleolithic implements, and to describe the experiments in flint fracture which were carried out, and which have convinced me that these flaked flints are undoubted works of man. I have endeavored to establish the fact that in this country we have evidence of a continuous evolution in the making of flint implements, which, commencing with the most primitive "eolithic" edge-trimmed stones, proceeded uninterruptedly and inevitably to the production of the well-known pointed and ovate paleoliths of the river-drift deposits.

I am perfectly well aware that such a view runs counter to the opinions held by the more conservative school of archæologists both at home and abroad, which, while not denying that the earliest paleolithic implements cannot represent the first efforts of man in flint-flaking, has nevertheless refused to believe that the races of pre-paleolithic people are represented, either by their flint implements or actual skeletal remains in this part of the country.[2] It has been the custom with some to look to Asia as the birthplace of mankind, an area, as Keith so truly states in a recent issue of *Man* (vol. 17, No. 5, May, 1917), "of which we know almost nothing, and therefore can believe it capable of anything." I have read with care the arguments put forward by various writers in support of this and similar hypotheses, and I have found them to be unsatisfying and unsatisfactory. I am unacquainted with a single valid reason for accepting the view that Asia witnessed the earliest stages of man's evolution, and moreover as this vast country is a veritable *terra incognita* to prehistorians, I regard it as useless and unscientific to engage in speculation as to what did or did not happen there in the remote past. But, as I know of no reasons why Asia should be regarded as the probable home of earliest man, neither am I familiar with any cause or causes which would preclude the area which is now England from having had that distinction. Thus from the standpoint of pure theory any one may favor Asia or England as his fancy prompts him.

When, however, we pass from the domain of theory to that of fact the situation assumes a different aspect. Of prehistoric Asia we know next to nothing, and therefore have no facts to rely upon; of prehistoric England on the other hand we know a great deal and have a multitude of facts at our disposal. What are those facts?

First and foremost there are the various pre-paleolithic flint implements which have been found in different parts of the country.

I have seen and examined such implements from the Kent plateau,[3] from ancient deposits near Salisbury, Peppard in Oxfordshire, Aldershot, and Selsey Bill in Sussex[4]. It would thus appear that these early flint implements occur over a very wide area, and further search will no doubt extend it still more. But it is in East Anglia where the greatest facilities exist for recovering evidences of pre-paleolithic man. In this district occur widespread glacial deposits of Boulder Clay and gravel, and beneath these in many places is found the Pliocene Red Crag surmounting a detritus-bed containing the débris of an ancient pre-Crag land surface.

In no other part of England is such a deposit as the Red Crag to be found, and in fact the Pliocene strata are almost solely confined to East Anglia.

It has been my good fortune during the past twelve years to have been able to investigate the Boulder Clay, Middle Glacial Gravel, and the sub-Red Crag detritus-bed in search of flint implements. These deposits are exposed in various pits sunk into the plateau in the neighborhood of Ipswich, and it is in this plateau that the present rivers have cut their valleys in which they have laid down the beds of gravel, etc., containing the normal paleolithic implements. A glance at Fig. 1 will at once show the reader the relation of these plateau beds to the valley deposits and demonstrate that the former are of a much greater antiquity than the latter. In Fig. 2 is shown a diagrammatic vertical section of these plateau beds, and we will commence by examining the lowermost and oldest stratum, the sub-Red Crag detritus-bed which rests upon the London Clay. The top of the London Clay was a land surface in pre-Crag times, and this land surface was eventually slowly submerged beneath the waters of the Crag Sea. The objects lying upon this ancient land surface, large and small flints, flint implements, pieces of bone, etc., were no doubt swept during this submergence into hollows or pockets in the London Clay, and finally covered by the sands and shells of the Red Crag Sea. The implements recovered from the detritus-bed are fashioned by bold and skilful flaking, and include the well-known rostro-carinate form, together with scrapers, borers, choppers, etc.[5]

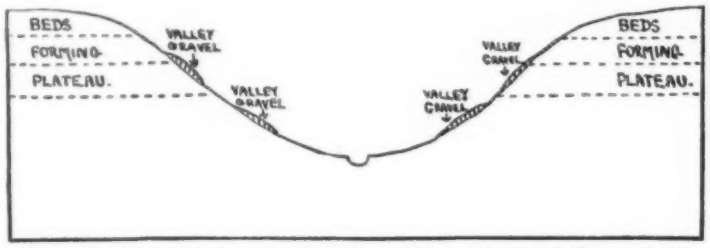


Fig. 1—Relation of the plateau-forming rocks to the river-laid gravels in the valley cut into the plateau

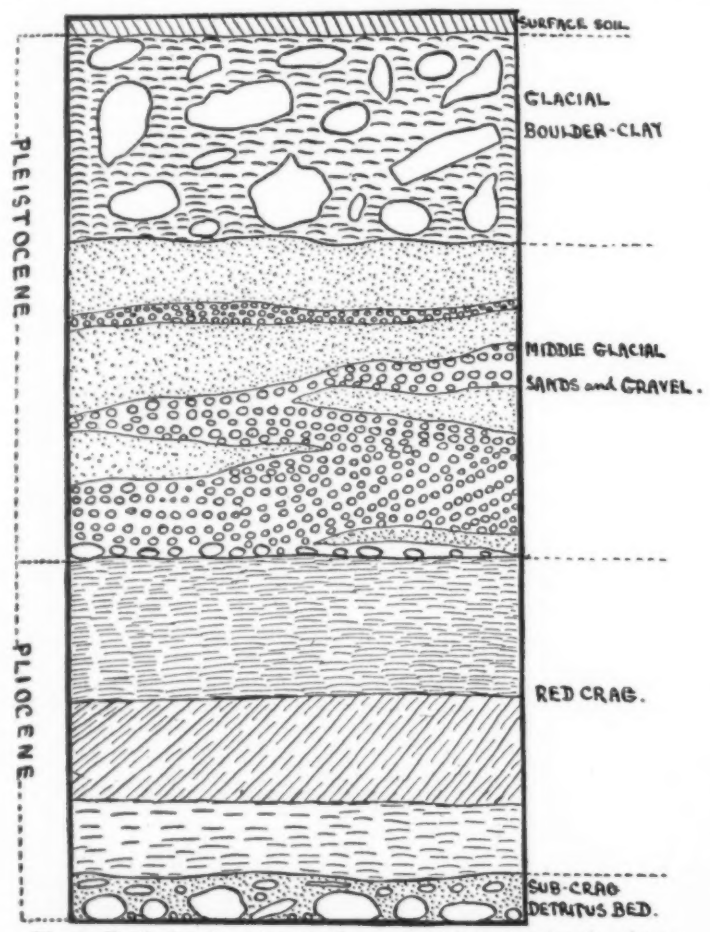


Fig. 2—Vertical section showing the principal beds forming the plateau Near Ipswich

Though these specimens occur sealed down beneath a definite Pliocene deposit, it is evident that they cannot represent man's first efforts in flint-flaking, and the earliest examples of his handiwork must in consequence be looked for in still more ancient strata.

The detritus-bed is generally about six to twelve inches in thickness, and the crag surmounting it may be twenty or more feet in depth. But it seems probable that during the succeeding glacial period a large amount of the crag was eroded away, and that originally, therefore, there was a much greater thickness than is now present. The Middle Glacial Gravel which usually overlies the Red Crag is of Pleistocene date, and supposed to be intermediate in age between the earliest glacial deposits of the Norfolk coast sections and the later Glacial Boulder Clay.[6]

This Gravel, which was probably formed by the breaking up and redeposition of an ancient land surface, contains flint implements of different ages, all of which exhibit flaking of a different order to that in vogue in pre-Crag times.[7] Above the Middle Glacial Gravel occurs the well-known Chalky Boulder Clay which is supposed to be the direct result of land ice during the glacial period. In this deposit I have found another series of humanly flaked flints which again differ in their technique from the succeeding Middle Glacial and pre-Crag specimens.[7] The three implementiferous beds I have described must not be supposed to represent all the geological strata which go to form the plateaux of East Anglia, nor must it be imagined that the Red Crag period was succeeded by the epoch in which the Middle Glacial Gravel was laid down. Between these two periods a number of other beds were deposited, but these are not represented in the Ipswich district. The Middle Glacial Gravel and Chalky Boulder Clay do, however, represent a correct sequence in point of time.

This brief account of the pre-paleolithic implements of East Anglia and elsewhere will serve to demonstrate that in England we have very clear evidence of the presence of races of people making implements of a primitive type and who lived prior to the time when the earliest paleolithic implements were fashioned.

That appears to me to be a fact of the first importance far exceeding in scientific value speculations regarding ancient, unknown Asia.

The second fact which, in my opinion, lends support to the view that the flint implements and actual skeletal remains of pre-paleolithic man are represented in this country, is afforded by the now famous discovery at Piltdown in Sussex. I confess I am somewhat loth to add fuel to the fires of controversy which since their discovery have raged round these ancient human remains. But in my judgment these relics have been so extraordinarily misinterpreted, both as regards their age

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*From *Science Progress*.

[1] "Flint Fracture and Flint Implements," *Science Progress*, No. 41, July, 1916, pp. 37-50; "The Oldest Flint Implements," *ibid.* No. 43, January, 1917, pp. 431-40; "The Relationship of the most Ancient Flint Implements to the later River-drift Paleoliths," *ibid.* No. 45, July, 1917, pp. 83-96.

[2] See for instance:—"Men of the Old Stone Age: Their Environment, Life, and Art," Henry Fairfield Osborn, 1916.—"Man the Primæval Savage," G. Worthington Smith, p. 2.

[3] "On the Primitive Characters of the Flint Implements of the Chalk Plateau of Kent," Sir J. Prestwich, *Jour. Anthrop. Inst.*, vol. 21, pp. 246-62.

[4] "The Sub-Crag Flints," J. Reid Moir, *Geol. Mag.* V., December, 1913, v. *10*, pp. 553-5.

[5] "The Flint Implements of Sub-Crag Man," J. Reid Moir, *Proc. Prehis. Soc. of East Anglia*, v. *1*, part 1, pp. 17-43; "On the Discovery of a Novel Type of Flint Implements. . . . Sir Ray Lankester, *Phil. Trans.* Series B, v. *202*, pp. 283-336, "On the Further Discoveries of Flint Implements beneath the Base of the Red Crag of Suffolk," J. Reid Moir, *Proc. Prehis. Soc. of East Anglia*, v. 2, part 1, pp. 12-31; "Implements of Sub-Crag Man in Norfolk," W. G. Clarke, *ibid.* v. *1*, part 2, pp. 160-8.

[6] *Geology in the Field*, part 1, p. 120 (F. W. Harmer, "The Pleistocene Period in the Eastern Counties").

[7] "Flint Implements of Man from the Middle Glacial Gravel and the Chalky Boulder Clay of Suffolk," J. Reid Moir, *Proc. Prehis. Soc. of East Anglia*, v. *1*, part 3, pp. 307-19.

and significance, that I feel it to be necessary to comment upon them.

As is well known, the late Mr. Charles Dawson, of Lewes, found at the base of a thin deposit of gravel at Piltdown portions of a very thick and massive human skull, associated with half of a remarkable human lower jaw.[8] This jawbone and a very large canine tooth found near it show in many respects distinct simian characteristics, while the skull, whatever its exact form and size may be, is clearly human in its characteristics.

Thus we find in this unique fossil a combination of human and simian characters, such as have been looked for by evolutionists ever since Darwin first enunciated his famous theory regarding the ancestry of modern man. But all evolutionists would agree that such a form would occur only at a very early stage of man's development, and this is a fact of great importance. Putting aside for the moment all considerations of the geological age of the Piltdown remains, and the type of flint implements found with them, we may say with confidence that the whole aspect of the bones, their condition of fossilisation and their half-human, half-simian character, point to a very great antiquity. How does the geological evidence affect such a conclusion?

The human bones were found in the lowermost stratum of a thin deposit of gravel resting at about 120 O.D. and approximately 80 feet above the level of the Sussex Ouse. The height at which any particular deposit occurs above sea or river-level is in itself of almost negligible value. Ancient beds may outcrop at a very low level, while much newer strata may occur at a considerable height above sea or river-level. I mention this to demonstrate that the antiquity of the Piltdown gravel cannot be determined by reference merely to the height at which it occurs.

It is necessary, therefore, to examine the actual strata composing the gravel-bed. Mr. Dawson, in his very accurate and careful examination of this deposit, recognized four well-defined strata,[9] and it was in the lowermost but one of these, resting upon "a pale yellow finely divided clay and sand," that the human remains were found. With these remains were found fragments of the bones and teeth of six different animals, two, and most likely three of which can be referred with certainty to the Pliocene period. The three other mammals, red deer, horse, and beaver, may or may not be of Pliocene date.

Of the beaver Dr. Smith Woodward states[10] that it is "most probably Pleistocene," while of the red deer he remarks that typical specimens "have never hitherto been found below the Pleistocene." The discoverers of these various relics at Piltdown draw attention to, and seem to lay stress on, the fact of the difference in condition of the specimens as regards the amount of rolling by water to which they have been subjected, and apparently attempt to drawn conclusions regarding their respective ages from such differences. My experience, however, has led me to place little value on the condition of any constituents of a deposit of gravel, and I have frequently found specimens of contemporaneous date and lying in close proximity to each other, some of which are rolled while others exhibit scarcely any signs of their transport. And if one attempts to envisage the multifarious varieties of treatment to which specimens in a gravel would be subjected during its deposition, such apparent paradoxes are not very difficult to understand.

I cannot but think that had no human bones been found in the Piltdown Gravel there would not have been such an evident attempt to place it in the Pleistocene period, and while it is without doubt wise to err on the side of caution in these matters, it is well to remember that over-caution may lead to as much misconception as over-confidence.

I see no reason why the lower stratum of the gravel at Piltdown should not be a Pliocene deposit overlain by gravelly strata of later date, and I know that such an association of beds of different ages occurs not infrequently in the valleys of East Anglia. *In a Supplementary Note on the Discovery of the Piltdown Skull*[11] Messrs. Dawson and Smith Woodward state, "We cannot resist the conclusion that the third or 'dark bed' is, in the main, composed of Pliocene drift, probably reconstructed in the Pleistocene epoch," and if, as I think, such reconstruction is *very* problematical, it is clear that the geological evidence does not conflict seriously with the view based upon the characters of the human bones themselves, that these bones must be of a very considerable antiquity. But it is when we turn to the evidence afforded by the flint implements found with the Piltdown person, that this great antiquity seems definitely established. If I, as a practical flaker of flint, had been shown Dr. Smith Woodward's reconstruction of the Piltdown skull and jaw, and had been asked what sort of flint implements in my opinion such a very primitive semi-human creature would be capable of producing, my answer would have been "the very primitive edge-trimmed flints generally known as eoliths."

I should not regard it as in any way probable that such an ape-like man would be able to make even the earliest of the pointed or ovate paleolithic implements, which I know from experience require much thought and skill to produce. Now if we turn to the excellent illustrations of the flint implements found *in situ* at Piltdown,[12] it will be realized that such a supposition is correct, as not a single example of a pointed or ovate paleolith appears among these illustrations. There are certainly some flints illustrated of which the legend reads, "Paleoliths from Piltdown," but I beg leave to dispute the correctness of this description. Some little time ago Dr. Smith Woodward very kindly gave me an opportunity of examining these specimens, and I at once recognized, as is also clear in the drawings, that the workmanship of the flints is quite distinct from the technique of the makers of the normal paleolithic implements. The ill-defined cones of percussion, and rough heavily truncated flake-areas of the Piltdown specimens, stamp them indelibly as the work of pre-paleolithic man, and further that their makers lived a long way back in the pre-paleolithic epoch.

I have found such specimens as these below the Pliocene Red Crag, and would refer the reader to an illustration in one of my published papers which testifies to the truth of this statement.[13] But when "It is realized that these particular flint implements, which as I have shown pre-Crag man was capable of making, are the latest found in the Piltdown Gravel, and that they occurred in a stratum less ancient than that containing the human bones, it will be seen that we are dealing with the remains of a person who in all probability existed at a period the remoteness of which makes the paleolithic epoch seem comparatively modern. For the only implements found in the "human" stratum and in intimate association with the Piltdown individual were the primitive edge-trimmed flints generally described as eoliths."[14] This particular type of implement represents, as I have shown in a former article in *Science Progress*,[15] the earliest efforts of man deliberately to shape flints to his needs. I have also shown in the same publication[16] that there is a very good reason to believe that these "eolithic" implements were the precursors of the rostrocarinate form found in the sub-Crag detritus-bed. Thus it would appear probable that the human remains from the Piltdown gravel must be referred to a member of the early pre-paleolithic period—and Piltdown is not in Asia.

There seems to me to be no escape from these conclusions. All I ask is that the antiquity of the Piltdown remains may be computed in the same way as the age of all other ancient human bones. In the case of the Neanderthal and other Pleistocene skeletons which have been found, their antiquity has been decided upon by reference to the geological strata in which they lay, and the fauna and flint implements with which they were associated.

If this method, the only possible method, is applied in the case of Piltdown, the evidence is quite overwhelmingly in favor of an early pre-paleolithic date for the human bones found there. There appears to be no possibility of regarding them as of paleolithic antiquity.

In my judgment then we have most definite and clear evidence that the pre-paleolithic peoples are abundantly represented in this part of the world. This conclusion is based on the following facts:

1. The discovery in various parts of England of different kinds of flint implements in deposits which are of greater antiquity than those containing the earliest paleoliths.

2. The discovery at Piltdown in Sussex of the remains of a very primitive type of human being in intimate association with certain definite Pliocene mammalian forms, and the earliest kind of flint implements known to science.

The neolithic and paleolithic stages in this country are fairly well known, but the vast pre-paleolithic periods await examination.

These periods are fully represented in England, and the flint implements, etc., contained in the deposits laid down during these epochs must be collected and investigated. Such an investigation, I submit, will show that the evidences of man's pre-paleolithic history are as abundantly represented here as in any other part of the world, and lead us to be careful in speculating as to unknown Asia's monopoly in this direction.

Vanadium from Waste

ACCORDING to the Stockholms Dagblad, a new industry has been established in Småland. The concentration of ores at Taberg throughout the course of centuries has left huge accumulations of waste. Recent research has revealed a content of vanadium in this waste. A Swedish company has purchased a portion of these old workings with a view to the extraction of the vanadium.—*Metall und Erz.*

The Viscosity of Gasoline

THE short-tube viscosimeters which are in ordinary use for determining the viscosity of lubricating oils cannot be used with gasoline, for which it is necessary to employ an instrument with a much longer outlet tube. The Ubbelohde viscosimeter, primarily designed for kerosenes, appeared suited to the purpose and two instruments of this type were used in determining the relation between time of discharge and viscosity in poises. By a large number of runs with water and ethyl alcohol solutions, liquids of known viscoscity, it was found that:

$$\text{Kinetic viscosity} = \frac{\text{viscosity in poises}}{\text{density, g per cc.}} = 0.00000887\ t - \frac{1.438}{t}$$

where t is the time of discharge in seconds. The published standard dimensions of the instrument give 0.125 cm. as the inside diameter of the outlet tube, and this was found to be 0.129 in the instruments tested. The time of discharge for 100 cc. of water at 20 deg. cent. (68 deg. fahr.) was found to be very close to the specified value of 200 sec. It is therefore suggested that 200 sec. should be retained as standard, but that the diameter of the outlet tube should be changed to 0.129 cm.

In dealing with highly fluid liquids such as gasoline, it is convenient to use the fluidity, or reciprocal of the viscosity in poises, in place of the viscosity. The temperature-fluidity curve is very much more nearly a straight line than is the tempegature-viscosity curve. Fluidities were found for thirteen samples of gasoline and one kerosene over a temperature range from 5 deg. to 55 deg. cent. (41 deg. to 131 deg. fahr.). These tests showed that kerosenes have a lower fluidity or higher viscosity than water, while gasolines, though varying greatly among themselves are all more fluid than water. This is an agreement with the published data in regard to kerosene; the available information in regard to the viscosity of gasolines is very meager.

It is generally recognized that the gravity test is an uncertain guide to the quality of kerosene or gasoline, if taken by itself without information as to the source of crude oil. This was confirmed by the tests on gasolines, their order when arranged according to densities being quite different than when arranged according to fluidities. A fractional distillation is often used as a substitute or supplement to the gravity test, and this gives valuable information. It requires, however, more complicated apparatus and greater skill than needed to test fluidity. Furthermore, the close relation between fluidity and vapor pressure, to which attention has been called by E. C. Bingham, points to the conclusion that fluidity may be an extremely good criterion for volatility.

Bingham gives tables for fluidities of various pure chemical compounds over a wide range of temperatures, and these tables were used to compare the fluidities of the thirteen gasolines with those of the aliphatic hydrocarbons. It was found that ordinary commercial gasoline, as now sold for use in automobiles, has a fluidity slightly less than octane. Most of the special gasolines, intended for use in airplane motors, have a fluidity between that of heptane and hexane. The temperature-fluidity curves of these gasolines were nearly straight and parallel, so that the order of the different gasolines, arranged according to fluidity, would be nearly independent of the temperature considered. It is suggested that the specification of fluidity at two temperatures might serve to define a desired grade of gasoline. (Abstract from Bureau of Standards Technologic Paper No. 125.)—*Mech. Engineering.*

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[8] "On the Discovery of a Paleolithic Skull and Mandible . . ." C. Dawson and A. S. Woodward, *Qtly. Jour. Geol. Soc.*, Mar., 1913, v. 59.

[9] "Supplementary Note on the Discovery of a Paleolithic Skull and Mandible . . . " *Qtly. Jour. Geol. Soc.*, April, 1914, v. 70, p. 83.

[10] "On the Discovery of a Paleolithic Skull and Mandible . . ." *Qtly. Jour. Geol. Soc.*, March, 1913, v. 69, p. 148.

[11] *Qtly. Jour. Geol. Soc.*, April, 1914, v. 70, p. 85.

[12] *Qtly. Jour. Geol. Soc.*, March, 1913, v. 69, Plates XVI and XVII.

[13] *Proc. Prehis. Soc. of East Anglia*, v. 2, part 1, Plate VIII. fig. B.

[14] *Qtly. Jour. Geol. Soc.*, April, 1914, v. 70, pp. 84 and 85, also Plate XIV.

[15] No. 43, January, 1917, pp. 431-40.

[16] No. 45, July, 1917, pp. 83-96.

Photography in Research*

A Concise Review of the Applications of Photography in Industry

By Arthur G. Eldredge

(Photographs by courtesy of "Chemical and Metallurgical Engineer")

INDUSTRIAL organizations and educational institutions have for some time recognized the value of photography, its chief uses being for records, graphic proof on progress of work, or illustrations for lectures. Investigators would do well to follow in such footsteps, since in science there is absolutely no other means of adequately recording the facts. Words fail completely to portray conditions. Drawings can but poorly convey the texture, minute detail or substance of an object as it really is. Photography does swiftly, accurately

Fig. 1—Feldspar by transmitted light. × 100. Same area as that in Fig. 2.

and easily these things which by other means are done laboriously or not at all.

Modifications of the simple camera have a limit to their accomplishments. The next step is the microscope. What remarkable things it does for us. On the other side of the eyepiece there awaits a new world, things indescribable, impossible of delineation. Photography steps in, it accentuates color contrasts or eliminates them, it will record the facts for which you seek if used with skill. In the living sciences it reveals for the masses those secrets with which few are acquainted. In mineralogy it shows by polarized light

Fig. 2.—Feldspar by polarized light under crossed Nichols. × 110.

rock structures we could not have guessed. (Figs. 1 and 2.) Modern metallurgical methods and products could hardly exist but for information revealed by the microscope. In this case photography can record the facts of structure and composition for quick comparison.

Surpassing all of these methods is the motion picture. In this instrument we have a tool outstripping the magic of Aladdin. It tells things we would not dare dream. It may prove beyond contradiction things be-

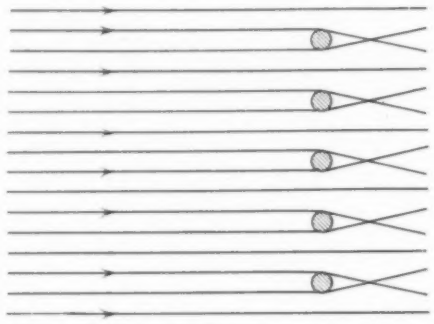


Fig. 3—Effect of diffraction on parallel light

yond the wildest conjecture. Our eyes are something of a compensating instrument—they can interpret only slow motions, and by reason of the persistence of vision are a complete failure in splitting seconds. Not so the motion picture; with it consecutive pictures of a moving object may be made with exposures varying from one-fifth of a second to one ten-millionth of a second. Pictures taken at excessive speeds when projected at the normal rate of 16 exposures per second permit one to analyze the motions and to understand things entirely beyond ordinary vision.

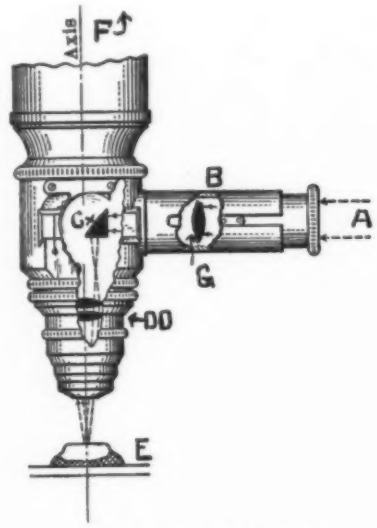


Fig. 4—Prism Illuminator

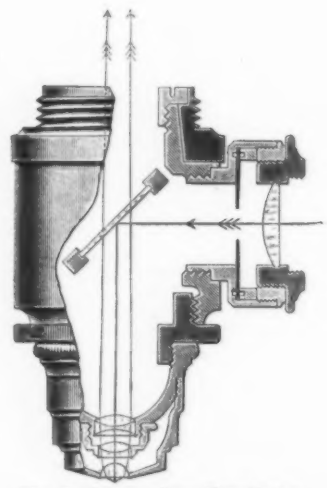
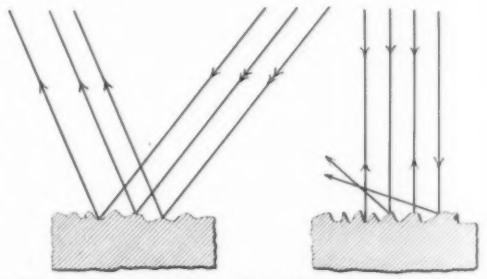


Fig. 5—Plane glass illuminator

In the field of research men are endeavoring to uncover the unknown, to do the "impossible," but are far too slow in adopting photographic methods. The moving picture and the microscope can see a million times quicker and smaller than the eyes. Unaided vision can recognize a two-hundredth of an inch, but not interpret it, while motions quicker than a tenth of a second run together; one cannot separate them. How, but for the microscope and photography, could we know the vast world beyond? It can show what is happening right down to the bare bones of matter and force.

LIMITATIONS OF OPTICAL LENSES.

Many who read this may not be thoroughly familiar with the optics of an optical or photographic microscope, so some of the principles affecting this work will be noted briefly. In applying photography to the microscope we find certain exacting conditions and narrow limits in which to work; the laws governing numerical aperture, resolving power and wave length are inflexible.



Figs. 6 and 7.—Oblique light (6) renders the subject dark and with few bright lights, altering the appearance of the relief. Vertical illumination (7) renders blacks as black and polished surfaces light

In working with opaque objects the problem is much different than with transparent objects. In the latter case the illuminating system passes the light rays directly through the specimen and into the microscope. The resolution of the system, or the power to render visible the various parts of the object, is an important consideration, as well as the thickness and quality of specimen, glass slide and cover glass. In low power work we are able to make full use of the resolving power of the lens and it is comparatively easy to obtain perfect results. As we understand it, resolution may be defined as the ability of an objective to render correctly the diffraction phenomena of a subject in transmitted light. If we place a rod in a stream of water the water flows around it. If we place a rod in a beam of light some of the rays no longer travel straight but bend around the edges of the obstruction—this we call diffraction. Such opaque lines in a subject may be several thousand per inch, when the diffraction image will be confusing and if not correctly rendered will lead to misinterpretation. (Fig. 3.)

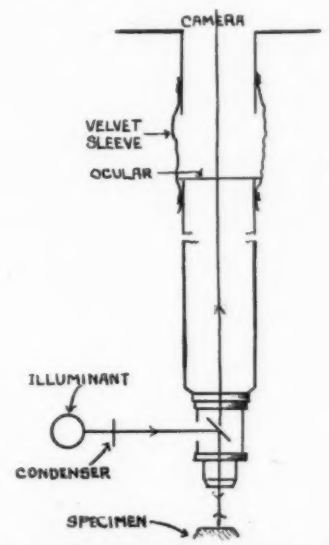


Fig. 8.—Arrangement of apparatus for making motion-photo-micrographs of opaque objects

*From *Chem. and Metallurg. Engineer* (New York).

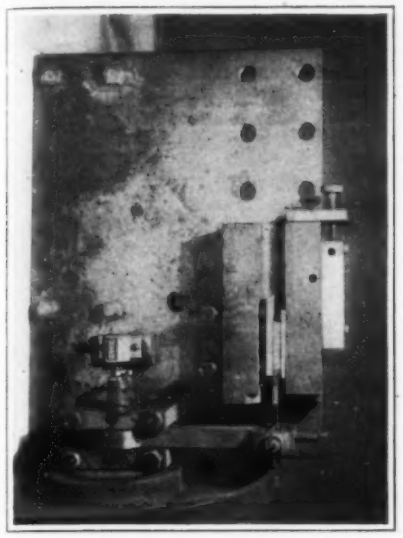


Fig. 9.—H. F. Moore's stressing machine. Rotation of the flywheel transmits vertical oscillation to outer end of test piece, producing bending at the rise.

In the case of opaque objects reflected light is used, the objective acting both as condenser and objective. At first sight it appears quite impossible that the objective can transmit light in one direction to illuminate a subject and transmit in the opposite direction the image of an object so illuminated without interference. Yet in this case one is concerned mostly with the defining power of the lens, rather than its resolution.

There is another important qualification for the microscope lenses—their correction for color. The ordinary microscope has achromatic lenses, that is to say, they are corrected for two regions of the spectrum so that there is little trouble with color fringes at low powers. A superior system of lenses is called apochromatic; these bring the three regions—red, green and blue—to a perfect focus with the image by the use of lenses of different kinds of glass, so that there are no color fringes. In using the microscope for ocular observation, color fringes, defects due to spherical aberration and lack of definition are not always serious defects, because the eye is something of a compensator and has "persistence of vision." In photography, color fringes destroy the sharpness of the image, while spherical aberration, producing different foci for central and marginal rays, permits only a portion of the subject to be clearly defined on one exposure, so the results may be not only unintelligible but misleading. The plate has no imagination, it records the facts as presented.

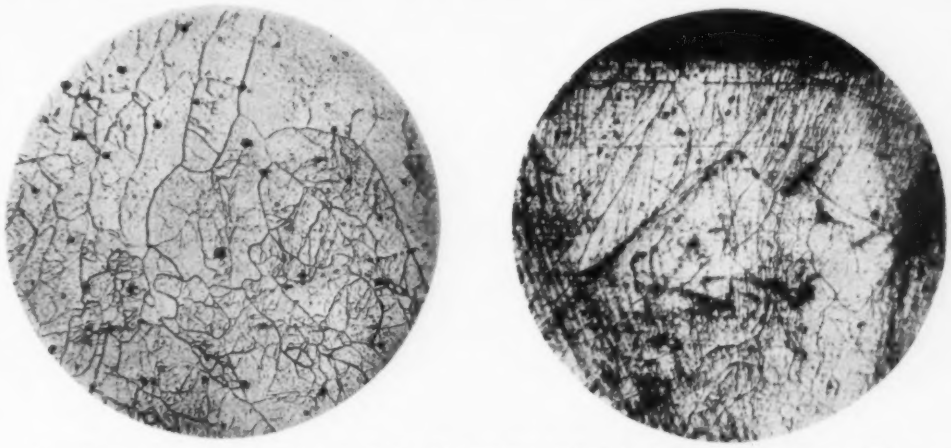


Fig. 12—Wrought iron before (left) and after (right) being subjected to bending stresses. × 200

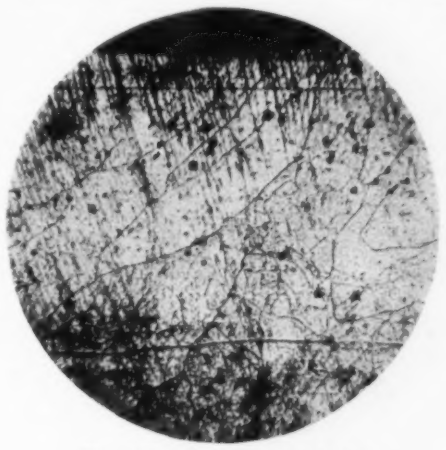


Fig. 13—"Slip lines" developing across the crystals

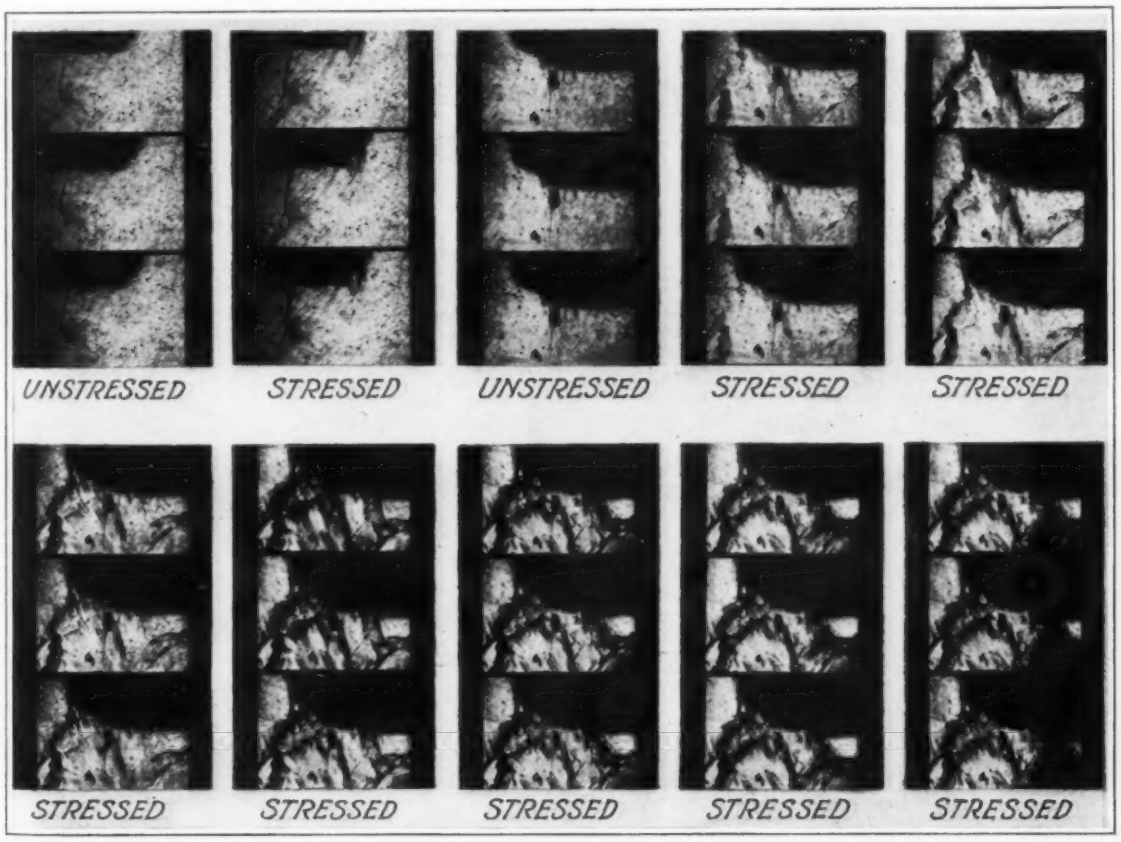


Fig. 11—Motion pictures through the microscope. Successive stages in repeated stress of wrought iron. Magnif. about 70

ILLUMINATION OF OPAQUE OBJECTS.

To illuminate an opaque object such as a piece of polished metal, a vertical illuminator furnishes the only correct rendering, but its use does impair the optical qualities of the objective. In the customary objective for transmitted light, the lenses are mounted at varying distances by different makers, and corrected for a cover glass over the specimen. For use with the vertical illuminator the lenses must be short mounted to avoid internal reflections and uncorrected for cover glass—none being necessary.

Figs. 4 and 5 illustrate two common types of vertical illuminators. With the plane glass reflector there is a tendency to produce a haze over the image, while with the prism there is a tendency to form a sculptured or relief image. Yet either gives satisfactory results under proper conditions.

From the illustration (Fig. 4) it is seen that the illuminant at *A* passes its light into the tube *B* (preferably in parallel rays) through the converging lens *G* which focuses the light source on the hypotenuse of the prism *C*, thence through the objective lenses *DD* which concentrate the light on the subject *E*. An image of *E* is formed by *DD* projecting it to the ocular *F* which not only magnifies the image but corrects errors of the objective.

Such illumination does not appear to be a difficult operation, yet under some conditions trying difficulties occur. For instance, it is essential that *AB* be at right angles to the microscope tube and that the lenses be clean and free from dust. (It seems quite impossible to keep dust from the lenses; it returns again and again.) The axis must be perpendicular to *E*, otherwise the specimen will not appear properly illuminated. It is seen in Fig. 6 that if the light is at all oblique the reflected rays which should pass into the objective will fall outside. The relief will be changed in appearance and the object will appear but partly lighted. In Fig. 7 the light falls vertically, most of it returns to the objective and the relief appears correctly.

ILLUMINATION FOR MOTION PICTURE CAMERA.

To make motion pictures through this apparatus it is necessary to place a motion picture camera at a short distance from the ocular *F*, as shown in Fig. 8.

The lenses are preferably removed, while magnification is changed by using oculars of various powers.

For motion work of this nature a flickerless light-source is necessary, as any fluctuations in illumination are recorded in the negative. The axes of light-source and of microscope must be at right angles horizontally and vertically, and the surface of the film must be at right angles to the axis of the microscope. Furthermore, all of the elements must be rigidly fixed. To comply with these conditions in a built-up apparatus requires considerable time and care. As a case at hand, some motion pictures of a wrought-iron test bar showing the mechanism of failure under alternating stresses were made for Prof. H. F. Moore of the Materials Testing Laboratory, University of Illinois, the designer of the fatigue machine (Fig. 9). I used a 400-watt gas-filled lamp of stereopticon type, the image of one filament only being employed, which was projected into

(*Concluded on p. 77*)

When Did Our Ancestors Take to Trees?*

Significance of the Divergence of the First Digit in the Primitive Mammalian Foot

By James Williams Gidley, U. S. National Museum

In connection with some recent research work on Basal Eocene mammals I have had occasion to make a critical study of the primitive mammalian foot, especially as regards the meaning of divergence of the first digit. On the interpretation of this character depends in no small degree our concept of the early life history of the Mammalia.

Based on certain modifications observed especially in the hind feet of marsupials, including divergence and opposability of the hallux associated with a tendency to enlargement of the fourth digit and reduction and syndactylism of the second and third digits, Huxley[1] in 1880 expressed the view that the existing marsupials have been derived from an arboreal ancestry. Later Dollo,[2] in full accord with this view, discussed the evidence for it at considerable length. Soon followed a review by Bensley[3] in which he expressed general agreement with the interpretation of Huxley and Dollo. In 1904 Matthew published an article on "The Arboreal Ancestry of the Mammalia,"[4] in which he accepted the views of Huxley, Dollo, and Bensley regarding the arboreal ancestry of the marsupials, and expressed his belief that the placentals are likewise of arboreal origin. This latter belief was apparently based, principally at least, on the fact that the first digit, in both the fore and hind feet of the early Eocene mammals of generalized type, is so frequently found in a divergent position, and on the condition found in the earliest known Primates. But unlike Huxley and Dollo, who considered arboreal adaptation in the marsupials a specialization and not a primitive condition, Matthew advanced the hypothesis that opposability of the first digit in the early mammals was a primitive condition. While I do in the main indorse Matthew's characterization of a hypothetical "common ancestral group," I am unable to agree with him regarding arboreal ancestry as applied to placentals in general, and therefore differ from him in the interpretation of the conditions found in the primitive mammalian foot. In order more clearly to set forth my own view I here quote the principal arguments advanced by Matthew in support of his interpretation:

(1) In the first place, as far as we can trace back the history of each of the arboreal groups, we find their first ancestors with the first digit as fully opposable as in the modern representatives (*e. g.*, the Middle Eocene primate *Notharctus*).

(2) Second, in those groups which have not an opposable thumb, we find as we trace back their ancestry that the trapezium, whose form and facets give the surest indication on this point, approaches more and more nearly to the type preserved in the Primates, etc.

(3) In the four Basal Eocene mammals (Pantolambda, Euprotogonia, Claenodon, and Dissacus) in which this part of the skeleton is known, the form of the bone [trapezium] is surprisingly uniform, and when the manus is put together, the first digit is thrown partly outward from the rest of the hand, and permits of much freer motion than the remaining digits, with a considerable degree of opposition.

Following this, in the same article, Matthew states that the primitive opposability of the hallux is less clearly indicated but suggests this is due to the probability that the evolution of the hind foot for terrestrial locomotion "began earlier or proceeded more rapidly." He further suggested that "the hypothesis that all mammals passed through a stage when the pollex and hallux were opposable," would explain among other things, "(*a*) the presence of but two phalanges on digit 1, three on each of the others; (*b*) the epiphysis of digit 1 being proximal as in the phalanges, instead of distal as in the remaining metapodials; (*c*) the anomalous musculature of digit I on all mammals, the object of which is clearly seen when the digit is opposable, but is quite unexplained otherwise." In further substantiation of the arboreal ancestry hypotheses, Matthew's first proposition above quoted has, I believe, little weight as evidence. First, because *Notharctus* can hardly be considered primitive, since the known species, even in the Bridger epoch, had advanced in foot, limb, and skull structure well toward the condition found in the present-day South American apes; second, admitting *Notharctus* to be primitive, the presence of true opposability in this genus can affect the proposition under discussion only so far as the Primates themselves are concerned, and cannot be taken as evidence of arboreal ancestry for other orders of mammals, especially as there is no indication of close relationship between any of them and the Primates.[5] At most the evidence in the case of *Notharctus* cannot be interpreted to mean more than that the group which it represents (the Primates) had adapted themselves to an arboreal habitat at a comparatively early period. But opposability probably followed or accompanied and did not precede their adaptation to tree-living habits. If this be true it explains why there are so many cases in which opposability has not been developed even in strictly arboreal forms, and likewise why these cases seem to be confined to species of comparatively small size. For example, many species of rodents and insectivores are living today almost exclusively in the trees, yet, so far as I am aware, there is not one example of true opposability among the Insectivora, and but one among all the Rodentia, living or extinct. This single exception is furnished by the African genus, *Lophiomys*, in which the first digit of the hind foot is thus developed, and this animal is not arboreal. Among the Insectivora some of the Tupalidae are mostly arboreal in habit, more so than in any other members of the order, yet even in this family there is not the slightest trace of opposability. Among the Primates themselves there is a whole group of living species, the South American marmosets, that, in the fore feet at least, show no evidence of opposability, although they are strictly arboreal in habits. These smaller, lighter-bodied animals seem never to have acquired the function of grasping a limb, but depend rather on their sharp, widely spread claws for support in progressing among the tree tops.

Matthew's second and third propositions, above quoted, do not strictly concern opposability but refer to simple divergence of the first digit. And the crux of the whole proposition seems to lie, after all, in the interpretation of this condition.

"Primitive opposability" and "more or less opposable" are terms which the advocates of arboreal ancestry have frequently used, but have never clearly defined. These terms seem to express a condition somewhat different from the kind of opposability developed in the modern Primates, and as used by Matthew, as I interpret it, seem to imply that simple divergence of the first digit may be taken as proof of opposability or at least former opposability. It becomes necessary then, to distinguish clearly between "opposability" and "divergence" of the first digit, as for an intelligent discussion, one should understand clearly what is meant by "opposability." As applied to arboreal adaptation opposability can imply but one condition, *viz.*, a modification which gives the power to grasp or hold, by opposing the first digit to the others, and this is always accompanied by a special and distinctive arrangement and development of the digital muscles. Opposability, it is true, is usually accompanied by a complete divergence of the opposing digit,[6] but divergence, in all stages, is frequently observed where there is no other evidence of opposability. Moreover, examples of divergence without opposability are found most frequently in the older Eocene representatives of almost all the orders of mammals in which the feet are known, while true opposability has not been found in any forms of older age than the middle Eocene; and here it is known only in species of a single order. These facts, together with the absence of opposability in tree-living rodents and insectivores, as already pointed out, would in themselves suggest that this condition of opposability is relatively modern in development, or at least not primitive; and in further support of this view it may be noted that in those orders in which opposability has been developed and retained, it is always most advanced in those species which are in other respects notably specialized. Thus, in the Primates, opposability, especially in the hind feet, is found best developed in the heavier, long-limbed monkeys and apes. It has reached its greatest perfection in the hand of man, although doubtless the higher stages of perfection of this function were accomplished after man, formerly arboreal, had finally taken to a terrestrial habitat. Contrary to what one might expect if opposability were a primitive condition, in the little marmosets of South America, which among living Primates are considered a rather primitive and generalized group, there is, as already stated, not the slightest approach to opposability of the pollex, which is long and functional and it is only moderately developed in the hallux. Yet these little animals are as strictly arboreal in habits as any group of the order. If opposability of the first digit is a primitive condition, then why is it so poorly developed in this particular group while so well developed and perfected in the more highly specialized members of the order? Granting that all Primates began their career in an arboreal habitat, it seems to me a more logical conclusion that the little light-bodied marmosets have never developed opposability, finding the primitive sharp claws sufficiently effective for clinging to the bark of trees, while the heavier-bodied forms, or those species which early formed the habit of swinging from limb to limb as a method of progression through the trees, very quickly took advantage of the *primitively divergent* first digit to develop opposability. This function once developed to a degree where the grasp became firm, the claws would no longer act as formerly, and the constant pressure thus transferred to the palmar side of the toe, or finger tops, would soon modify them into the "nail," so characteristic of the Primates.

If by the term "primitive opposability" is meant simple divergence of the first digit, it seems to me purely assumption, based on no convincing evidence, to interpret this condition as denoting an arboreal habitat. This interpretation moreover, seems not warranted without the most positive proof, especially when such a foot as that of *Claenodon*, for example, or any other primitive mammalian foot of the basal Eocene types shows no evidence of true opposability and, moreover, could be derived, with such comparatively slight changes, directly from the primitive reptilian type of foot. In fact it is but a short step in mechanical adaptation from the reptilian state to the type of foot of which *Claenodon* is a somewhat advanced example. On examining a foot of *Sphenodon* or other reptile of generalized type, the distinctly reptilian characteristics seem to be these: Foot completely plantigrade; metapodials all more or less divergent, permitting free spreading of the digits; metapodials shorter than phalangeal portion of the digit; first digit shortest; fourth digit longest of the series; phalangeal formula digits I to V, 2, 3, 4, 5, and 3 or 4, respectively. Comparing now the type of foot under discussion. The following seem to be the principal modifications which mark its advance over the reptilian type: The foot has remained plantigrade with the metapodials shorter than the phalangeal portion of the digit and with digit IV, though relatively shortened, still longest of the series; digits II to V are drawn somewhat more closely together, but are still capable of considerable spreading; the first digit, retaining more or less its original reptilian position, is left more divergent than the others; and the phalanges of the median two digits are reduced to the mammalian number, three in each digit.

These simple modifications seem to be purely mechanical adaptations brought about in changing from the reptilian crawling manner of locomotion, to the mammalian walking gait, and each modification may be readily explained on this hypothesis. In the normal position a reptile or batrachian carries the feet well out from the body, with the toes directed more or less outward in such a manner that the short first digit is directed first inward then forward toward the end of the stride, the heel remaining on the ground, so that normally the weight of the body is not brought fully on the ends of any of the metapodials. In terrestrial mammals, even of the most primitive plantigrade type, the feet are brought more under the body in walking, the radius and tibia, respectively, are brought to the inside, the first digit pointing con-

(*Continued on page 76*)

*Reprinted from *Jour. Washington Acad. Sciences.*

[1] Proc. Zool. Soc. Lond., p. 655.

[2] *Les ancêtreses Marsupiaux étaient-ils arboricoles?* Miscellanées biologiques, 1899.

[3] Amer. Nat., 1901, *35*: 117-122.

[4] Amer. Nat., 1904, *38*: 813-815.

[5] In my opinion, there is some evidence that this important order, and probably some other orders of mammals as well, have been derived independently from different though probably more or less closely related premammalian ancestral groups.

[6] An exception to this is seen in some of the phalanges in which the first metacarpal is closely appressed to the second, but the toe is opposable and divergent in its phalangeal portion.

Life of Brass Condenser Tubes*

Results of a Study of the Actions of Certain Metals in Distilled and Sea Water, and Possible Protective Measures

By Drs. Guy D. Bengough and O. F. Hudson

THE fourth report of the Corrosion Committee, which was presented at the meeting of the Institute of Metals, is divided into three parts. In the first the authors, Dr. Guy D. Bengough and Dr. O. F. Hudson, discuss the actions that take place when certain metals and alloys corrode in distilled water and sea water. In the second they consider the behavior of condenser tubes in similar liquids and the variations in the behavior of different samples of tubes having nominally the same composition; and in the third they set forth a statement in some detail of the practical problems of corrosion.

After a brief consideration of the current theories of corrosion, the report discusses the difficulties in the way of making a true quantitative determination of the amount of corrosion, and shows that in certain cases they are almost insoluble with existing methods of analysis. Mere "loss of weight" measurements, unsupported by detailed examination, of scale and metals in solution, are regarded as being of little value in many cases, and it is thought they might advantageously be replaced by microscopic work.

NATURE OF ACTION.

The action of distilled water on metallic zinc, the authors conclude, is initially a process of chemical oxidation rather than of electro-chemical displacement. Normally metallic zinc is covered with a partially protective scale consisting largely of oxide or basic carbonate. Water containing carbon dioxide can attack or dissolve the oxidized layer, and a true metallic surface is then exposed to the action of the water. Where this takes place a peculiar form of oxide is formed on the surface; it probably contains zinc peroxide and exerts a catalytic action on the underlying metal. Being slightly soluble it passes into solution, and is afterwards largely precipitated as the ordinary hydroxide and carbonate. The precipitated hydroxide has a distinctly protective action on the metal beneath it, reinforcing the original scale and enabling it to resist the action of carbon dioxide. The action is thus localized. With very dilute acid, such as acetic, the action consists in the replacement of hydrogen by zinc, but the action is not severely localized, as with distilled water, there are no local accumulations of the products of corrosion, and consequently the action is more nearly uniform. There is no evidence that dissolved oxygen can act as a depolarizer; hydrogen is given off as gas. The action of sea water on zinc is also chemical rather than electro-chemical, and local action is again due to the local accumulation of certain products of corrosion. The principal action of distilled water and of sea-water on copper is also one of chemical oxidation.

The action of distilled water on 70: 30 brass is considered to be the chemical oxidation of the copper and zinc and the partial solution of the oxidized products. Much of the zinc, in the presence of carbon dioxide, passes into solution, and part of the copper. The residue of both metals remains on the surface of the alloy as an oxide scale, and this becomes further oxidized and altered at certain spots which become covered with thick deposits of the products of attack. Such deposits are porous, and allow, and probably accelerate, local attack on the underlying metal. The attack is accompanied by redeposition of copper by displacement by the zinc either electro-chemically or otherwise, and precipitation of cuprite. There are signs of slight local dezincification at such places, but the attack over the general surface of the alloy is complete corrosion. The positions at which local attack and pitting take place are not determined by the variation in the electrical properties of the original metal, but by the conditions of the experiment. In the presence of dilute acids, such as hydrochloric and sulphuric, local action of the type described does not occur, since there is little or no local accumulation of oxidation products. On the other hand, the absence of carbon dioxide, retards the action. From the analytical data it appeared that the local action in the case of distilled water increased with time, while the rate of general corrosion over the whole specimen fell off. These facts suggest the fallacy of loss of weight test, since local action is more important practically than general corrosion.

The action of sea-water on brass has been studied on the same lines as that of distilled water. The action is considered to be similar in type. Local pitting and dezincification are due to the accumulation of the products of corrosion. Under certain conditions redeposition of copper may occur. The rate of general corrosion is much greater than that in distilled water, and does not fall off so rapidly with time. At the ordinary temperature there is less tendency to local dezincification.

BEHAVIOR OF CONDENSER TUBES.

In studying the form of the surface of certain condenser tubes of 70: 30 brass, the presence of a layer that differs in its behavior towards corrosive agents from the underlying metal has been identified in several different ways. In many cases this layer is probably richer in copper than the alloy beneath it. In such cases the tube may resist dezincification in a marked degree for long periods; in other cases the surface layer probably has nearly the same composition as the rest of the tube, and in such cases strong dezinicification may take place in sea-water in the neighborhood of 50° C. Tubes from the same batch of manufacture usually resemble one another as regards the nature and properties of the layer, and tubes from different batches, even though made by the same maker, may differ. Thus one important factor as regards dezincification is the nature of the tube, but the kind of surface that best resists dezincification does not necessarily best resist other kinds of attack. Means of controlling the surface layer have not yet been worked out, but the problem does not appear to be insuperable.

In many cases local action may be initiated on condenser tubes by the action of certain bodies, which themselves appear to take no direct part in the action. Such bodies are sand, calcium carbonate, ferric hydrate, glass, clinker, and coke. The amount of action that takes place varies with the physical properties of the substance. The action is associated with the accumulation of products of corrosion, and may be largely assisted by them. The nature of this action is of well-marked type, and has been provisionally called oxide disintegration. It is usually characterized by intercrystalline oxidation. Actions of this kind are of great importance in many cases of corrosion on the practical scale.

PRACTICAL ASPECTS.

As a preliminary statement of the practical problem of the corrosion the authors propound that the ordinary 70: 30 brass tube of commerce is not liable to any electrolytic action set up by anodic and cathodic areas inherent in its surface, even in the presence of good electrolytes such as sea-water. It is corroded, under normal conditions, by a slow chemical action, which produces a slight roughening of the surface, but no well-defined pitting. Unless this action were speeded up locally by factors independent of the tube, the life of a tube would normally be 15 to 20 years or more in the case of deep sea-water, and many types of neutral fresh water. If acid be present in the water in the proportions of only a few parts per 100,000, the speed of attack is greatly increased, the action being a general thinning of the tube. Neutralization is quite effective in stopping this increased action.

The following conditions are set forth as those under which a tube would have a normal life of 20 years. In practice tubes fail sooner because the normal slow roughening of the tube by chemical oxidation is locally speeded up by factors which are for the most part independent of the tube:—(*a*) Only clear water to enter the tube, or water that will not deposit suspended matter. (*b*) The water must be free from gases in suspension, and must not contain more than the normal amount of air in solution. (*c*) The water must be neutral or not more than very slightly alkaline. It must be free from ammonia and certain other specially harmful substances, which are, however, of comparatively rare occurrence in technical waters. (*d*) The temperature of the cooling water in the hottest part of the condenser should not exceed 35° C. (*e*) The speed of the water should be about 5 or 6 feet per second. (*f*) The steam should be properly distributed in the condenser, according to the best modern practice.

A water supply which varies considerably in composition at different times of the year involves special problems and must be excluded from the above statement at present.

EFFECT OF SCALE.

It is not uncommon to find a dozen or more different substances among the scale on a tube, and each of these substances will exert some influence, greater or less, harmful or protective, on the underlying tube. To a limited extent the nature of the scale on a tube can be modified, and it is probable that it is in this direction that work can be most usefully pursued in the endeavor to prevent certain types of corrosive action. In sea-water, estuarine water, and some other waters the scale contains calcium carbonate in larger or smaller amounts. The physical character and the distribution of this substance may be one of the most important factors in determining the nature and amount of the corrosive action that takes place.

The distribution and the effect on corrosion of this substance are, in the authors' experience, most nearly uniform when the tubes are maintained as cathodes in sea-water by some form of electrolytic protection. Under these conditions the layer is usually extremely thin and extends over the whole tube. It does not entirely prevent the disintegration of the underlying metal, but appears to slow down the rate considerably. When ordinary condenser tubes are used in sea-water, and certain other types of water, without any special electrolytic protection other than that afforded by the cast-iron water ends, a fairly continuous layer of calcium carbonate scale is found only for a distance of from 5 to 10 inches from each end of the tube. It usually appears to be coarser, thicker, and less uniform than that formed under the conditions already considered. It appears to retard corrosion, but to be less effective than the thinner, more uniform, and more compact layer, characteristic of continuous protection by a current generated outside the condenser. On the general surface of the tube farther away from the ends a continuous layer, more or less free from other substances, is not found as a rule, though isolated areas are sometimes covered with such a layer; but for the most part the calcium carbonate, if present at all, is mixed up with products of corrosion.

In the case of hard fresh waters, such as are used in the Northampton district, the carbonate scale may be of formidable thickness, especially with slow water speeds and low vacuum. Under such conditions it is coarse in structure and porous. It is not entirely protective, even when it is so thick as to interfere seriously with the efficiency of the condenser.

In certain cases, such as estuarine waters, where the nature of the water varies at different times of the year in accordance with the rainfall, it is probable that there is a continuous process of solution, deposition and resolution of the calcium carbonate of the scale going on in accordance with the chemical conditions set up at different periods by the varying composition of the water. Tubes that have been subjected to such conditions show discontinuous layers of carbonate scattered about the tube, which suggest that some such action has taken place. In such cases a rapid attack may be proceeding over certain areas of tubes which are free from scale, while other areas are largely protected.

The protective power of calcium carbonate may be considerable, but is not absolute even under the most favorable conditions yet investigated; moreover, it varies considerably in accordance with its physical condition. It has also been found in the laboratory that calcium carbonate, precipitated under certain conditions, may be very harmful and initiate corrosion in much the same way as does sand.

PROTECTIVE MEASURES.

The authors give a brief summary of their observations on the Cumberland method of electrolytic protection as applied at the power-station of the Brighton Corporation at Southwick. They say it seems clear to them that this process ensures a prolonged life for the tubes provided that they had not begun to corrode before it was applied. If severe corrosion has begun before the process is applied, or if it is applied imperfectly, it is by no means certain that it will be stopped by the process.

As it does not seem likely that the problem of preventing local pitting will be solved by improvements in composition, it may in certain circumstances be desirable to add to the resisting power of the tube by

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*Summary of report to Institute of Metals from *Times Engineering Supplement* (London).

Progress In Naval Aircraft

(*Continued from page 67*)

each. On test these ribs were required to carry a proof load of 450 lb. of sand for 24 hr. without damage. An interesting detail of the wing construction is the hinged leading edge which encloses the control cables to the ailerons or wing flaps. This eliminates the air resistance of these cables, but at the same time they are accessible for inspection by merely swinging up the leading edge on its hinges. The wings are arranged as a biplane with the necessary struts and wires to give girder strength. For lightness the struts are made up as a spruce box, but to decrease resistance this square portion is enclosed in a fish-shaped fairing or "stream line" of stiff fiber. To reduce any tendency of the struts to bow under load, the middle points are connected with a steel cable. The diagonal bracing between wings is by steel cables in pairs. These cables are arranged to lie one behind the other with a spruce batten between to reduce air resistance.

The metal fittings where struts and wires are fastened to the wings presented a serious problem. The forces to be taken care of were so large that it was necessary to abandon the usual methods of the airplane builder and adopt those of the bridge designer. All forces acting at a joint pass through a common center. In this case, as in a pin bridge, the forces are all applied to a large hollow bolt at the center of the wing beam. In the design of the metal fittings to reduce the amount of metal needed, it was decided to employ a special alloy steel of 150,000 lb. per sq. in. tensile strength. To increase bearing areas, bolts and pins are made of large diameter but hollow.

GUARDING AGAINST CORROSION.

The steel work being highly stressed, it is especially necessary to protect it against salt water corrosion. The development of the present Navy standard practice may be of interest at this place. At the start of the war aircraft fittings were copper plated and in some instances the copper plating was covered by nickel plating. If the plating became scratched or abraided, moisture and air were admitted and very rapid corrosion would ensue, the iron being electro-positive to the copper or nickel and thus forming a primary battery.

Recognizing the fact that zinc is a metal that is strongly electro-positive to iron, the Bureau decided to eliminate copper and nickel plating and to use in place thereof galvanized coatings produced either by the hot dip, electro-galvanizing or sherardizing processes. Metal thus treated, even when abraided, is protected from corrosion because of the strong electro-positive nature of the zinc, which has a high protective influence upon any adjacent areas of steel that may be uncoated or abraided. Since the hot dip process operates at a high temperature, approximately 375 to 475 deg. cent., it might injuriously affect certain types of heat-treated steel alloys and the electro-galvanizing method is used wherever possible and is required for all alloy steels. Through the assistance of the Bureau of Standards a plating expert was obtained and sent to the different factories to install this process. After the parts are galvanized they are then coated with naval gray enamel, which is either air dried or baked on. It has been found that the enamel adheres well over the electro-galvanized part and a fitting is obtained which has given excellent results on exposure to salt water for a long period of time. This is considered a development of great importance since so much trouble has heretofore been had with improperly coated metal fittings.

Aluminum is used to a considerable extent in the construction of aircraft instruments and it has been found that rather rapid corrosion of the aluminum may ensue when exposed along the seacoast. For this reason aluminum instruments have been coated usually with spar varnish, or naval gray enamel. The results obtained have been very good and it is probable that coatings of this type will be used in the construction of certain parts of the aluminum strength members of rigid airships. The Bureau has under way a series of exposure tests at different points along the coast to determine the resistance of various aluminum alloy sheets to corrosion. There has been recently developed in this country at the request of this Bureau aluminum alloys which are of themselves highly resistant to atmospheric influences regardless of any coatings.

Various types of soldering flux and paste have been used in different aircraft contractors' plants. The largest use for these has been in the soldering of splice terminals on wire cables. It has been found that whenever certain of these soldering compounds are used, rapid corrosion of the cable occurs, as the compounds contain acid ingredients which work down into the strands. Examination of a great many samples of different types of soldering compounds show in practically every instance a very large proportion, from 20 to 80 per cent. of zinc chloride, sometimes admixed with ammonium chloride or mineral oil. The purpose of the zinc chloride is to have present a material that would hydrolize to an acid reaction which would cleanse the surface of the metal by dissolving the oxides and make a good soldering surface.

It has been found that the use of such compounds can be done away with entirely, and one cause of corrosion eliminated by the use of a soldering flux free from mineral acid. The flux consists of rosin with an organic acid compound such as stearic acid, these two ingredients being melted together in equal quantities by weight. This material has practically no solvent effect upon metal but cleanses the surface sufficiently from the oxide to present a good soldering joint. Some slight difficulties were at first had with contractors who endeavored to make up their own soldering compound to the above formula, reports being to the effect that they did not get sufficient cutting effect with the compound. These instances, however, showed that they had purchased stearine in place of stearic acid. Stearine, as is well known, is a glycerine ester of stearic acid and has no acid value, being neutral. Stearic acid, on the other hand, has a high acid value of 200, and when used with rosin forms a soldering flux that gives very satisfactory results.

PROTECTING THE WOODEN AND FABRIC PARTS.

Besides protecting the metal parts, it is necessary to protect the wooden members and their glue joints. Ordinary paint is fairly satisfactory but too heavy. The common varnishes and shellacs are not watertight enough. Through the early efforts of the Bureau cooperative work was done to develop a type of spar varnish that would give astisfactory results upon hulls, wooden parts and wing surfaces of Naval aircraft. After this varnish had been developed and specifications issued, manufacturers soon learned the method of producing it and within a short period of time it was found on the market in great quantities and at a reasonable price. The base of the varnish is tung oil. This varnish has been found highly resistant to water and has been used with most satisfactory results. At the same time there was developed a naval gray anti-actinic enamel, using as its base the same varnish previously referred to ground with certain pigments to produce the desired color and light stopping property.

The protection of the fabric wing covering becomes of added importance on the NC boats on account of the great area involved and the expense and difficulty of renewal. At one time, wings had to be recovered very frequently, but with the present Navy standard doping practice, the fabric stands up under favorable conditions from 6 months to a year.

To cover the NC surfaces about 6,000 sq. ft. of fabric has to be treated requiring over 200 gal. of dope. There are two types of dope in use at present by the Navy Department. These are known as cellulose nitrate and cellulose acetate dopes. The latter is produced from cotton treated with acetic anhydride and acetic acid, while the other is made in a manner similar to the production of gun cotton through the use of cotton treated with nitric and sulphuric acids. The acetyl or the nitrate group is taken up by the cellulose to make a new compound which is soluble in certain solvents. The treated cotton is then dissolved in solvents such as methyl, amyl, propyl, butyl or ethyl alcohol, acetone, etc., subsequently adding other non-solvent thinners such as benzol alcohol or benzene. Different kinds of softeners and fire-resisting salts are then added to the dopes. These are usually high-boiling, slow-evaporating liquids. Diacetone alcohol is a representative of this class. Triphynyl phosphate is used for its fireproofing value. A small quantity of urea is sometimes used to prevent the acidity which may be caused over periods of storage.

The present Navy practice in doping fabric is to apply first two coats of acetate dope because of its higher fire-resisting value and because of the fact that the acetyl radical present is ordinarily not injurious to fabric. There is then applied three coats of cellulose nitrate dope. A very taut surface is obtained. Naval gray enamel is then applied in one or two coats according to the wing surface to be treated. With this practice no difficulty has been experienced with scaling or cracking of the wing enamel. On the other hand, when five straight coats of acetate dope are used very serious scaling and cracking of the subsequently applied enamel will take place. The cellulose nitrate dope, moreover, is very much cheaper than the acetate dope, is readily available, has greater covering properties and gives greater tautness to the fabric.

The use of the wing enamel referred to has been a curious development which dates back to the examination of rudders on some planes that were in use in Florida several years ago. The fabric was found to be rotted in several places but in perfect condition where covered with the naval aircraft insignia paint. This indicated the value of the paint in shutting out the actinic rays of the sun. From that time on the Navy has used an anti-actinic wing enamel.

(*To be continued*)

When Did Our Ancestors Take to Trees?

(*Continued from page 74*)

stantly inward and the other more or less directly forward. The result of this modification would be to bring the weight of the body more exactly on the ends of the median toes, especially at the finish of the stride at which time the heel is raised clear of the ground. This would have a tendency to stiffen the wrist and ankle joints, through a closer articulation of their bony elements, to bring the divergent metapodials more closely together, an dto shorten the median pair of toes. This change in position of the feet and consequent change of the manner in which the toes are applied to the ground in walking may have been the primary cause of the reduction in phalanges of digits III and IV, and would quite satisfactorily account for the divergence of the first digit so frequently found in the primitive mammalian foot. It will be especially noted that the first digit is shortest, and in the mammalian position of the foot is so placed as to take no considerable part in the function of walking, hence it has been least modified and soonest lost in terrestrial forms which acquired a digitigrade gait.

It is plainly obvious that, from a central type of primitive mammalian foot similar to that just described, in which the first digit is unreduced, it is but a short step to true opposability. The divergent first digit could readily be converted into a grasping organ, and the modification to opposability doubtless was soon accomplished by those forms which early adopted an arboreal habitat. But among ground-living forms, in the other direction, it was an equally short step to the strictly terrestrial digitigrade type, in which the first digit was gradually atrophied, as it became functionless through being raised from the ground, and in many species has been lost altogether. In the process of development of the digitigrade type the functional metapodials are brought closely together and have become relatively lengthened while the phalangeal portion of these digits becomes shortened. It is through these stages of development that have come directly the modern ungulate types of feet. Still another type developed from the primitive terrestrial mammalian foot, or possibly directly from the reptilian stage, is that type of which the short-toed amblypod and probosicidian feet are examples. In these forms the toes remain more or less spreading, and all, including the first when present, function in bearing the weight of the body. In this type of foot the heel may become raised from the ground as in the digitigrade type, but this modification is always accompanied by the development of a pad so that this portion of the foot still functions in carrying its share of the body-weight as in the plantigrade type. It may be further assumed that the various aquatic types of feet are directly derivable from some such foot as that of *Claenodon*.

It would thus seem that the primitive mammalian foot, of the central group, must have been primarily terrestrial, and from this generalized type of foot, with *divergent* but not *primarily* opposable first digit, have been developed all sorts of modifications of foot structure, each adaptable to the kind of environment chosen, and that *divergence of the first digit is primarily an inheritance from the primitive reptilian condition*, and cannot be considered as in any way supporting the hypothesis of an arboreal ancestry of the Mammalia. It is likewise quite as apparent, it seems to me, that true opposability of the first digit wherever found should be considered a direct specialization of the primitive condition brought about by a mechanical adaptation to a peculiar (arboreal) life habit.

This viewpoint is certainly not weakened and seems to be strengthened by the difference in type of modification observed in the hind foot of marsupials as compared with that of the Primates. In the former, as observed by Huxley, opposability of the first digit is accompanied with enlargement of the fourth digit, and reduction and syndactylism of the second and third digits, while in the latter there is no approach to either of these modifications. This difference seems to be fundamental, and suggests that the marsupials took to tree-living habits at a somewhat earlier stage of development while the fourth digit was yet considerably longer than the others, and for that reason more directly opposed by the first digit.

Photography in Research

(*Continued from p. 73*)

the tube by the condensers of a No. 0 delineascope. An arc was found to be not only too intense but too variable in color and position. A gas-filled bulb with only one filament would be very desirable, while the Nernst or the new incandescent lamp as used for motion picture projection might answer well. It is best to absorb the heat from the light with a water cell. A prism illuminator was used with an achromatic objective and a compensating ocular, as these oculars give much better results than a Huyghenian.

MOTION MICROPHOTOGRAPHS.

All types of motion cameras are not readily adaptable to these special problems. Devices have been constructed for making motion pictures in various lines of research, notably at the Marey Institute in France. For my purpose I found the Bell and Howell camera an incomparable instrument. It is entirely of metal, compact and mechanically faultless. The rotating lens turret and the sliding base permit the focusing aperture to be moved to the exact position occupied by the film when recording.

As shown in Fig. 10 (omitted)[1] the camera and the stressing machine are clamped very firmly to a substantial table—a masonry pier would be more desirable—and the camera is then connected to the microscope by a black velvet sleeve to facilitate adjustments and to break the transmission of any vibration. A device for observing the action continuously by eye might be inserted but would result in some loss of definition. The microscope was first focused on a polished region at the base of the shoulder, shown in Fig. 9, where the stresses will be most intense.

Photographs of metals are usually at low power—one hundred or less. In making motion pictures the magnification was even lower in order to exhibit a sufficient field for study. This leads to more difficulty, because in the low magnification, the lines made by the crystal boundaries become so narrow that it is difficult to retain them in negative and positive with enough density to project well. It is possible to improve the sharpness of the image by using deep colored screens, preferably in the blue-green, thus eliminating other colors which might form color fringes. If this is done, panchromatic film is necessary. By

LIMITING RESOLUTION

Objective	N.A.	Yellow line D λ = 5896 A.U.	Green line E λ = 5269 A.U.	Violet line Hγ λ = 4341 A.U.
	⅛ .10	8,617	9,641	11,699
	¼ .25	21,542	24,103	29,247
	⅜ .6	51,700	57,846	70,193
	½ .9	77,550	86,769	105,289
Oil immersion	1/12 1.4	120,638	134,974	163,783

the accompanying table of resolving powers for transmitted light it is seen how much the working qualities of lenses are improved by increasing the numerical aperture and decreasing the wave length. Violet light is difficult to use, however, because the eye works very poorly in that region and it is quite impossible to focus the object, even with a magnifier. Sections of the film made in the present instance are shown in Fig. 11, while exposures of the same test made at higher powers with an ordinary metallographic microscope are shown for comparison in Figs. 12 and 13. In the results shown here the negative was made on positive film at the normal speed of 16 pictures per second, giving an exposure of 1/48 of a second, the negative film being too fast and not giving satisfactory contrast.

The little work which I have done in this field and the consideration of other special problems lead me to think that the motion camera with and without the microscope offers a means of research the value of which we can hardly predict. The field of application is as wide as human knowledge. Processes and reactions in the natural sciences and phenomena in the physical sciences will unfold many opportunities as we search for new facts. Special apparatus has been constructed whereby consecutive exposures can be made, each in one ten-millionth of a second. With such a tool, the transmission and reaction of sound waves might be quite readily photographed in motion.

One day some one may record the passage of electrons discharged across a vacuum. We can hardly set a limit.

[1] Details of the camera, microscope, etc., were illustrated in the SCIENTIFIC AMERICAN, for Oct. 26, 1918, p. 328.—EDITOR.

Pressure Casting of High Tensile Copper Alloys

Two sets of copper alloys, prepared during the years 1915-1918 in the Metallurgy Department of the National Physical Laboratory in order to combine high tensile strength with great ductility, were described before the Institute of Metals by Dr. W. Rosenhain and Mr. D. Hanson. The requirements they had to meet involved extensive cold working, and they had to be capable of being rolled into thin sheet which was required to have an excellent finish and to undergo further operations without cracking.

In the first series, in which it was desired to avoid the use of zinc, the copper was alloyed with aluminum or manganese, or both. One alloy of this series, containing 7 per cent. of aluminum but no manganese, attained in the "as rolled" condition a tensile strength only just under 40 tons per sq. in., with an elongation of 17.5 per cent., and after annealing a tensile strength of 27.5 tons and the remarkable elongation of 71 per cent. These results were closely approached by another alloy with 7 per cent. of aluminum and 1 per cent. of manganese; "as rolled" it gave 35.5 tons tensile and 28 per cent. elongation, and when annealed 29.3 tons tensile and 65 per cent. elongation. Similarly remarkable results were obtained with an alloy containing 6 per cent. of aluminum and 3 per cent. of manganese, and two with 5 and 7 per cent. of manganese without aluminum were interesting, though their figures were distinctly lower than those for the alloys containing aluminum.

In the second set it was required that no aluminum and not a high percentage of zinc should be used; the alloys were required to stand severe stamping and drawing operations in the form of thin strip less than 0.05 in. thick. None of them had such remarkable properties as some of those in the first set, but one containing 3 per cent. of manganese and 10 per cent. of zinc had in the cold-rolled condition a tensile strength of 47 tons with 3 per cent. elongation, and when annealed 23 tons tensile with 35 per cent. elongation.

Difficulties were encountered in casting the alloys of the first series owing to the presence of foreign mattter floating on the surface of the molten metal, which, in spite of every care found its way in small quantities into the mould. Finally an adaptation of the pressure casting method patented by Mr. F. Tomlinson, of the Broughton Copper Company, was employed with considerable success. The principle consists in forcing the liquid metal, by means of externally applied air pressure, through a feeder tube communicating with the bottom of the mould and dipping into the molten metal nearly to the bottom of the crucible. It is necessary to use a previously heated feeder tube, through which the metal can be forced without splashing and without exposure to the atmosphere, the dross, charcoal, etc., being left in the crucible. The amount of metal in the crucible must be so adjusted that the mould is filled before the bottom of the feeder tube is exposed. When the metal approaches the top of the mould the rate of flow is gradually reduced till it is almost arrested. At this stage a crust is formed on the top of the ingot. As soon as this is sufficiently thick, the air-pressure is gradually raised to 30 lb. per sq. in. and is maintained at that value till the ingot is solid. A fairly hot mould must be used, else the metal is liable to be chilled in the narrow orifice through which it has to pass. Conditions should be so arranged that this orifice remains open until the whole of the ingot is solidified. In the experiments the mould was preheated in a special gas furnace in such a manner that the bottom of the mould was distinctly hotter than the top, the bottom temperatures being of the order of 500 to 600° C. Even during the short time necessary for casting, the manganese-copper alloys become covered with a thick black coating of oxide, which ruins the ingots; the addition of 0.25 per cent. of aluminum prevents oxidation and entirely removes this defect.—*Times Engineering Supplement.*

What is a Chemical Element?

(*Continued from p. 69*)

expected. Moreover, the period of eka-tantalum, as estimated from the range of its α-rays by Hahn and Meitner, makes it appear that in due course determination not only of the spectrum, but also of the atomic weight and complete chemical nature, of this element will be possible. It is only in this way that the open question whether the actinium series branches off as shown at uranium-II or at uranium-I can be settled.

As the figure shows, so far as the changes have been followed, they all result in the production of isotopes of lead ranging in atomic weight from 206 to 210, the main products being that of uranium, 206, and both thorium products in the two branches, 208. The conclusion that lead was the ultimate product of thorium was new, but the prediction that the ultimate products of both uranium and thorium are different isotopes of lead—the one with an atomic weight less, and the other with an atomic weight greater, than that of common lead, 207.2—has been completely confirmed by experiment, and it has also been shown that ionium has an atomic weight lower than thorium (compare *Nature*, July 19 and 26, 1917).

The older chemical analysis of matter distinguished only heterobaric heterotopes. The newer methods depending on radio-active change distinguish, not only heterobaric, but isobaric isotopes, and also isobaric heterotopes—that is, substances of different atomic weight and identical chemical character, of the same atomic weight and different chemical character. A glance at the chart will show many examples of all three kinds. Not only has the chemical element been robbed of its time-honored title to be considered the ultimate unchanging constituent of matter, but its title to be considered homogeneous has also vanished. The century that began with Dalton and ended with the discoveries by Becquerel and the Curies took the practical conception of the element it found extant, as that which could not be further resolved, and made of it the central conception of a theory of the ultimate constitution of matter. The element was first atomized, and then the atom and the element became synonyms, related as the singular is to the plural. Every one of the conceptions which associated the atom with the chemical element now has to be modified. Atoms of different chemical elements may have the same atomic weight; those of what the chemist and spectroscopist regard as the same element may have different atomic weight; and, most difficult to include of all to anyone today attempting to define the chemical element, even though the atoms all have the same weight, the element, nevertheless, may be an unresolvable mixture of fundamentally different isobaric isotopes. Present-day complete identity may conceal differences for the future of paramount importance, if ever transmutation is practically realizable at will. The goal that inspires the search for the homogeneous constituents out of which the material world is composed is now known to be, like infinity, approachable rather than attainable. The practical and necessary conception of the chemical elements, as understood before these discoveries, is, of course, unaffected. It had, and it has, a real significance as representing the limits of the spectroscopic and chemical analysis of matter, which remains, though it is now known to convey something very unlike the original and natural conception of the elements as the *l m n's* of the material alphabet.—*Nature.*

Life of Brass Condenser Tubes

(*Continued from p. 75*)

special treatment before it goes into use. Such treatment, for instance, may be the production on the tube of a resistant scale by artificial means. Such a scale may consist of oxide, calcium carbonate, or a basic salt, or a mixture of these substances. The simplest, but not the most efficient, case of such a scale is an oxide scale produced upon the alloy by treatment in an annealing furnace in an oxidizing atmosphere, and a number of experiments have been made with tubes treated in this way.

The treatment in the case of 70: 30 brass, lead, brass, or Admiralty alloy is to heat the finished tube in an oxidizing atmosphere for half an hour at a temperature of about 260 to 300° C. It is then put into use with the oxide scale on it—*i. e.*, without pickling or further treatment. It has been found that this heat treatment does not affect the mechanical properties of the tube sufficiently to interfere with the making of a tight joint by the use of ferrules. (The heating periods and temperatures are different for metals or alloys other than those mentioned.) The process is known as the pre-oxidizing process. It is important that the tubes treated by this process should have a good surface, smooth and uniform. Harm may result if the heating temperature much exceeds the limits stated.

Tubes of various types of brass, treated in the way indicated, have given good results so far at Brighton, in comparison with ordinary tubes of similar composition, but it is not yet certain that such tubes will resist the active attack set up by certain deposits. A considerable number of treated tubes are under test in various parts of the country, under different sets of conditions, and the results of these tests will be reported in due course. Preliminary tests seem to show that treated lead, brass, and Admiralty tubes resist dezincification to a marked degree in ordinary seawater.

Finally, it must be emphasized that it is not likely that either tubes treated as described, or any other type of tube producible commercially, will be found satisfactory under all conditions. A tube and its treatment must be chosen to meet the particular conditions in which it will be used, but it is hoped that the number of types of tube and treatments required will be small. They may, perhaps, be eventually reduced to two, a copper type alloy and a selected brass alloy.

Flotation for the Practical Mill Man

By F. G. Moses

(*Concluded from Scientific American Supplement 2272, page 48*)

RECLEANING FLOTATION CONCENTRATES.

The practice of refloating concentrates produced on rougher cells as a means of increasing their purity is nearly universal at the present time. A short consideration of some of the factors influencing the results obtained by this practice will be of interest.

Successful recleaning of the flotation concentrates in cleaner machines involves several factors: (1) The general idea of all concentration that the grade of the product from a concentrating machine will be higher the richer the feed to the apparatus, (2) the fact that gangue material in flotation concentrate can be eliminated by re-forming the froth under more quiet conditions than those under which it was first produced, (3) making the amount of froth smaller in proportion to the amount of mineral to be lifted, tending to give concentrates of the highest possible grade.

If these facts are true, and they are generally assumed to be so, we can say that the effectiveness of the recleaning or reflotation operation will depend on the following: (1) The ratio between the capacity of the cleaner cells and the amount of the concentrate to be refloated, (2) the purity of the first concentrate produced for recleaning, (3) the skill used in the operation of the recleaning machines, (4) the extraction obtained in the cleaner machines, and (5) the water dilution of the froth being re-treated.

Before proceeding to discuss these points, one fact should be emphasized that is usually assumed to be true but is seldom mentioned: Nearly all minerals have the property of adhering to flotation froth but, of course, in widely differing degrees. An extreme illustration would be the case of limestone and galena. They have both been made to float, and their commercial separation by means of flotation depends only on the degree with which one floats in preference to the other under given conditions.

On this assumption, it follows that when several minerals are present, the most readily floatable will be the first attracted to and carried by the froth, and when the froth has picked up all of the mineral possible and there is still remaining space available this space will then be filled by the next most easily floatable mineral in the pulp, and so on.

With these facts in mind, it should be quite simple to see the importance of having the cleaner cells of a correct size to produce the correct amount of froth to take care of the mineral that is coming to them in the rougher concentrate. As already mentioned, the amount of froth produced on a flotation machine in a given time is a definite and limited quantity. The amount of froth produced, therefore, should be just sufficient to carry the amount of pure mineral that will come to it from the rougher cells and no more. As the quantity of froth produced will depend on the size of the froth discharge area, other things being equal, the necessity of having the correctly proportioned cleaners should be clear. Practice has shown the above to be true. Several illustrations could be shown where the grade of the final concentrate has been very materially improved by simply decreasing the number of cleaners that were being used.

It follows that the number of cleaner machines in a mill does not depend on the number of rougher machines in the plant but on the number of pounds of concentrate that each rougher produces in a given time.

The effect of grade of feed and its relation to the purity of the cleaner concentrate should be easily seen, especially in view of what has just been said. The higher the grade of the feed to the cleaners, the less are the impurities that are to be eliminated from it, and the less is the work the cleaners will be called upon to do. Usually the grade of the concentrate that is produced for recleaning is determined by the extraction to be made on the roughers, which in turn is determined by economic conditions. This factor is, therefore, to a large extent outside of the control of the operator, except in the more limited sense.

The skill of the operator will probably be shown to a greater extent in the operation of the cleaner cells than in any other manner. He must be taught to run the machines so that just the correct amount of froth will be made and discharged to carry out of the machines the pure mineral that is coming to it, and no more. This can only be done by thoroughly understanding what the machines are expected to do, and closely observing their action from day to day.

It should not be necessary to emphasize the fact that cleaner cells must make the highest extraction possible, consistent with making the necessary grade of concentrate. An excessive loss at this stage of the process only means an excessive quantity of mineral to be returned to the roughers in cleaner tailings, salting the circuit and placing an added load on the roughers, with the increased chance that some of the mineral will be lost in the final tailings, giving an excessively low extraction for the complete operation.

At the same time, it has been shown that grade of concentrate can only be increased by a certain loss in extraction. It is, of course, necessary that the cleaners be so operated that a sufficiently high grade of concentrate is produced. A comparatively poor extraction will therefore be made in the cleaners. Economic considerations will govern this phase of the operation of the cleaner cells. It is common practice, and also logical under many conditions, to operate the cleaners to produce the highest grade of concentrate possible to be made when producing at the same time cleaner tailings equal in valuable mineral to the original rougher feed. This is not always possible, however, and must be governed by other conditions to a great extent.

The last point in the operation of the cleaners is the dilution of the concentrate being cleaned on them. This again brings us to the consideration of the relation of the quantity of froth and the amount of mineral to be saved. The quantity of mineral going to the cleaners should be so regulated that the amount of mineral going to the machine is just sufficient to load the froth. The point that should be watched is to have the pulp dense enough so the mineral actually in the feed will do this. When this is not the condition, it can often be remedied by making less froth on the cleaners or by using less oil on the roughers, causing them to make a froth containing less water. Another remedy would be to reduce the number of cleaners. The desired extraction usually limits the use of these remedies.

When the pulp in the cleaners is too thick and water is needed, only fresh, pure water should be used; under no conditions should return water carrying flotation oil be employed. Return water will carry enough oil to increase the cleaner froth and aggravate the conditions it is used to rectify. The cleaner, to produce concentrate of the maximum purity, should be rather under- than over-oiled.

CONCLUSIONS.

Several possible sources of unsatisfactory results in the flotation plant have been suggested with possible means for remedying them. In many cases, however, it will be found that the employment of these suggestions will not improve results as had been expected. In most cases, this will not be surprising. When the innumerable factors that can influence flotation results are remembered, it is little wonder that the varying of one or even two of them will make no evident improvement in results. It is only by long contact with the problem, and the understanding of all the various factors and their inter-relations, that the hoped for results are obtained.

Many operators, in striving for perfect metallurgical results, lose sight of the economic side of the situation. Unfortunately, very often, especially in flotation, the correction of or the improvement in one step of the process will only be to the detriment of some other step. This fact must always be borne in mind. When in doubt as to whether the apparent benefits derived from the improvement of some point in the operation are really justifiable, the profit sheet, the true standard of success of all technical operations, should be appealed to for guidance.

The Railways of Japan

By K. Yamaguchi[1]

JAPAN is far away from here geographically, separated by the Pacific Ocean, but industrially and economically the United States and Japan are very closely related, and it seems to me as though there were no ocean dividing us.

In 1872 the line between Tokio and Yokohama, the mileage of which was about 17 miles, was constructed, managed and operated by our government. In the years following, many other lines were constructed throughout the country, some operated by the government while others were run by private companies, their total mileage being in 1906 approximately 5,000 miles.

In the course of time we began to feel the difficulties naturally arising from the two forms of management, there being lack of unification and various complications. After close investigation the government finally took over the main lines of the country through the passage of a bill by Parliament in 1906. By this new law the government purchased 17 lines which had previously been owned by private companies, running through the main parts of the country, leaving a few branch lines to private companies. At present the total mileage of government lines is about 6,082 miles and about 1,200 miles are under construction, the mileage owned by private companies being 1,916 miles.

[1]Resident Representative, Japanese Government Railways.

Besides those there are in Formosa, Manchuria, and Korea, 2,383 miles of line, but these are controlled by their own governor general and are not included in the details which follow.

We have on the railways of Japan itself 2,917 locomotives, of which 700 are superheated, and 62 are Mallet articulated locomotives, the heaviest being 95 tons. Passenger cars are classified as first, second, and third class, and we have also sleeping, dining and observation cars. The total number of passenger cars is about 7,058; nearly half have bogie trucks, the other half being four-wheeled cars. All new cars, however, are to be of the bogie type.

As to freight cars we can boast 47,570, the capacity of 15-ton cars being our standard. They are nearly all four-wheeled, but there are some coal cars having a capacity of 24 tons of all-steel construction and with bogie trucks.

The Japanese islands being mountainous, it is somewhat difficult to construct railroads, and we have been obliged to build many tunnels and bridges. It is therefore impossible to make straight roads. The sharpest curve on the main lines is 15 chains (nearly 10,000 ft. radius), and the steepest gradient is 1 in 40 or 2.5 per cent. The gage of our railroads is 3 ft. 6 in., and the rails are 60 lb. usually, but we also have 75 lb. rails on heavy traffic or mountainous lines, and these rails are to be put in general use.

We use the chain and screw couplings, except on Hokkaido Island. That island being 60 miles from the main island the automatic center couplers were originated there and have continued to be used after the American practice. We have found these automatic center couples much safer and more economical and I am glad to inform you that we are going to place them in operation on all lines instead of our former chain and screw couplers.

Owing to Japan's industrial development our railroads were pressed by extraordinary increasing traffic and to meet these demands we have been forced to increase the supply of cars and locomotives and make vast improvements in our roads and terminals.

Last year we purchased 150 locomotives, 2,500 freight cars and 200 passenger cars, all of which were built in our own country. Unfortunately, it was not possible for us to secure all the necessary materials for construction and improvement of roads, terminals and repairs of equipment, so we recently made purchases in this country amounting to about $10,000,000.

We are always endeavoring to improve our management and operation in general in order to keep transportation facilities adequate to the development of the country. To gain this object our government railways despatch every year several officials and engineers to this country and Europe for the purpose of investigating and studying railroad systems and management.—*Railway Age.*

Mineral Resources of the Republic of Georgia

THE southwestern part of Caucasus between the Black Sea and the Caspian Sea, which was an independent State for more than 2,000 years prior to its conquest by Russia in 1801, has formed an independent republic called Georgia. The country has an area of 38,500 square miles with about 3,500,000 inhabitants.

The climate is pleasant, with an average temperature of 68° F. throughout the year. The natural resources are considerable, there being an abundance of water power available, as well as deposits of good quality coal that can be worked cheaply. Wool, cotton, and silk of excellent quality are produced. The richest deposits of manganese in the world—from which 35,000 tons were exported annually before the war—are in the Sharopan district, in the province of Kutais. They have been proved for a length of 93 miles, varying in thickness from 1 ft. 6 in. to 10 ft., and contain black oxide (MnO_2) and "Wad" ($Mn_2O_3(OH)_3$ with 50 per cent. of pure manganese. The phosphorus does not exceed 0.15 per cent. There are considerable deposits of high-grade copper ore containing 34 per cent. pure copper, and 12 refineries worked on German methods exported 20,000 tons of copper annually before the war.

Deposits of rock-salt, lead, silver and cobalt, and part of the well-known Baku oil-fields are within the territory of the new republic.

The country should prove of importance to engineers as soon as shipping through the Dardanelles is free.—*Teknisk Ukeblad.*

One Year of Air Mail Service*

THE air mail service has been in operation between Washington, Philadelphia and New York 1 year, and has demonstrated the practical commercial utility of the airplane. A year ago when the first flight attracted universal interest, the establishment of the service was regarded generally as experimental and of doubtful results; today it is an established branch of the postal service. A new route, from Cleveland to Chicago, has been inaugurated. The route from New York to Cleveland, which will connect up the New York-Chicago service, will be put in operation as soon as the equipment is completed, and other extensions will follow.

The two airplanes on the Washington-New York route are the same that carried the mail a year ago and have been constantly in the service and they are propelled by the same engines. One of these has been in the air 164 hours, flying 10,716 miles, and has carried 572,826 letters. It has cost, in service, $65.80 per hour. Repairs have cost $480. The other plane has been in the air 222 hours, flying 15,018 miles, and has carried 485,120 letters. It has cost, in service, $48.34 per hour. Repairs to this machine have cost $1,874.76. The record of the entire service between New York and Washington shows 92 per cent. of performance in the entire year, representing 128,037 miles traveled and 7,720,840 letters carried. The revenues from airplane mail stamps amounted to $159,700, and the cost of service $137,900.06.

PRACTICABILITY OF SERVICE DEMONSTRATED.

The operation of the airplane mail service every day in the year except Sunday, encountering all sorts of weather conditions and meeting them successfully, has demonstrated the practicability of employing the airplane for commercial service, and the air mail organization has been able to work out problems of great value in the adaptation of machines to service of this character. From the inauguration of the service until August 10, the flying operations were conducted by the Army, in connection with its work of training aviators for the war. Since that date it has been operated entirely by the Postoffice Department with a civil organization. When the service was started there was great diversity of opinion among aeronautical experts as to the possibility of maintaining a daily service regardless of weather conditions, and the opinion was held by many that it would have to be suspended during the severe winter months. The service has been maintained, however, throughout the year with a record of 92 per cent., gales of exceptional violence and heavy snow storms being encountered and overcome. Out of 1,261 possible trips, 1,206 were undertaken, and only 55 were defaulted on account of weather conditions. During rain, fog, snow, gales and electrical storms, 435 trips were made. Out of a possible 138,092 miles, 128,037 miles was flown. Only fifty-one forced landings were made on account of weather and thirty-seven on account of engine trouble. It has been demonstrated that flying conditions for such a commercial service as this which is regulated by a daily schedule regardless of the weather, are very different from those of military flying. Airplanes designed wholly for war purposes are not suitable for commercial service, as they lack the strength necessary for daily cross-country work with its incidental forced landings. Aeronautical engineers have developed for the Postoffice Department a stronger and more powerful plane suitable for commercial service, while retaining the excellent flying qualities of the De Haviland machine. The De Haviland Fours which were transferred to the Postoffice Department after the signing of the armistice are being reconstructed to fit them for commercial requirements. In specially constructed mail-carrying planes, for the building of which the department called for bids to be opened June 2, a form of construction is specified which will enable a mechanic to make important minor repairs in flight, making it possible with multiple engines to avoid forced landings.

One of the lessons learned from the operation of the air mail service during the year is that the element of danger which exists in the training of aviators in military and exhibition flying is almost entirely absent from commercial flying. Second Assistant Postmaster-General Praeger, in reporting to the Postmaster-General on the operations for the year, says that the record of the air mail service, which includes flying as low as 50 ft. during periods of marked invisibility, throws an interesting light on this question. During the year, more than 128,000 miles having been traveled, no airplane carrying the mail has ever fallen out of the sky and there has not been a single death of an aviator in carrying the mail. The only deaths by accident which have occurred were that of an aviator who made a flight to demonstrate his qualifications as a pilot and that of a mechanic who fell against the whirling propeller of a machine on the ground. But two aviators have been injured seriously enough to be sent to a hospital. Other accidents consisted mainly of bruises and contusions sustained by planes turning over after landing. Of the three types of planes operated regularly in the mail service one type was more given than the others to turning over on rough ground, and it was principally on planes of this type that pilots were shaken up or bruised. One type of machine in the mail service, which has performed almost half of the work, has never "turned turtle." The record of the air mail service with respect to accident will compare favorably with that of any mode of mechanical transportation in the early days of its operation.

NECESSITY AND LIMIT OF VISIBILITY.

One of the first studies to be taken up by the air mail service was to determine whether visibility is absolutely necessary to commercial flying. The first step necessary was the refinement of the existing radio direction-finders to eliminate the liability of 3 to 5 per cent. of error. This has been successfully worked out by the Navy Department on an air mail testing plane. The second problem was that of guiding the mail plane, after it had left the field, to the center of the plot for landing. This problem has been solved by the Bureau of Standards in experiments conducted on the air mail testing plane in connection with the radio directional compass. This device is effective up to an altitude of 1,500 feet, and by the further refinements of the device another thousand feet is expected to be added. Aeronautical engineers are working upon a device for the automatic landing of a mechanically flown plane, which will meet the condition of absolute invisibility that could exist only in the most blinding snow storm or impenetrable fog.

A year's flying in the mail service, with all types and temperaments of aviators, has established the fact that 200-ft. visibility from the ground is the limit of practical flying, although a number of flights have been made with the mail between New York and Washington during which a part of the trip was flown at an altitude of 50 feet. The basis of objection by aviators to flying above a ground fog, rain, snow or heavy clouds with one-engine planes is the possibility of the engine stopping over a village, city or other bad landing place, with the radius of visibility so narrow as to afford no opoprtunity to pick out a place for landing. It is generally accepted that with two or more engines forced landing under such conditions can be avoided.

SEVERE WEATHER CONDITIONS OVERCOME.

A number of severe gales have been encountered during the flights between New York and Washington. Gales of from 40 to 68 miles per hour have been met and overcome. Pilot J. M. Miller, formerly a flier in the naval service, made a flight from Philadelphia to New York in a Curtiss R-4 with a 400-hp. Liberty engine, rising from the field against a 43-mile gale and arriving in New York through a blinding snow storm, the wind velocity being reported by the Weather Bureau to be 68 miles per hour, and actually 15 per cent. greater at the altitude at which he flew.

Mr. Praeger states in his report that it has been learned that it is useless to send a plane having a top speed of no more than 75 or 80 miles against a 40-mile gale. "The two types of plane of this speed in the air mail service," he said, "are the Standard JR 1 mail plane, having a wing-spread of 31 ft. 7⅝ in. Each plane of this type is equipped with a 150-hp. engine, which does not provide enough reserve power to combat the disturbed air conditions at the surface in a wind of more than 40 miles per hour, especially if the wind comes in descending columns or gusts. Under these conditions it is possible to make headway only with a Liberty engine, which has plenty of reserve power. A plane equipped with a 150-hp. engine, if it succeeds in breaking through the surface winds, can make only slow and laborious headway against a full or a quartered headwind of about 40 miles. There have been many instances where the planes equipped with 150-hp. engines have been held down to a speed of between 30 and 37 miles per hour and also many instances where a 100-mile per hour plane equipped with a Liberty engine has been held to between 55 and 60 miles. A few wind-storm conditions were encountered where the planes at the height of the gust were actually carried backward."

The same six planes that were in operation at the inauguration of the service and have been in continuous employment during the year are in operation today, and the one which made the initial flight from New York to Washington, May 15, 1918, made the flight May 15, 1919. This is regarded as throwing new light on the question of the life of an airplane and as demonstrating that the mechanical requirements and the operation in commercial flying are more economical and safer than in military flying.

The fact that there were only thirty-seven forced landings due to mechanical troubles during flights makes a record not heretofore approached in aviation and is creditable to the American-built airplane and the mechanics who keep them in fine condition. This record is especially a strong tribute to the American-built Liberty and Hispano-Suiza engines.

Transportation by airplane is ordinarily twice as fast as by train and in the case of distances of 600 miles or more, no matter how frequent or excellent the train service, the airplane mail at the higher rate of postage should justify the cost of its operation. Wherever the train service is not as frequent or as fast as it is between Washington and New York, the airplane operations should show an immense profit on all distances from 500 miles up. With large airplanes and over greater distances a substantial saving in the cost of mail transportation on railroads would be made, besides cutting down the time of transit by one-half.

*From *Jour. Soc. Automotive Engineers.*

Sub-Antarctic Whaling*

By Dr. S. F. Harmer, F.R.S.

THE history of whaling in northern waters, and of the hunting of sperm whales in warmer seas, has often been written, and some of the principal facts relating to these subjects are matters of common knowledge. There is reason to believe that the existence of a whaling industry, which was inaugurated just outside the South Polar circle after the commencement of the present century, is by no means generally known. Although Capt. Cook, Sir James Ross, and others had many years before reported the presence of whales in those latitudes, no practical advantage was taken of the information until fourteen years ago; and since that date the industry has eclipsed in importance all that had been done previously, even when the Greenland whale "fishery" was at its height.

In 1892 Capt. C. A. Larsen left Norway for the Far South, which he reached in October of that year. No whaling was done, and an expedition to the same regions, fitted out by Capt. Svend Foyn in the next year, was also unproductive of whales, mainly for the reason that it had been intended to hunt right whales and sperm whales. The Norwegian captains brought home, however, a very vivid impression of the enormous number of whales frequenting sub-Antarctic waters; and the fact that they at first made no further ventures was due to the profitable nature of the whaling in the neighborhood of the Norwegian coasts. Dr. W. S. Bruce had simultaneously (1892) accompanied four vessels of the Dundee whaling fleet to the Antarctic, and had been similarly impressed with the abundance of whales in these waters. A meeting was shortly afterwards held in the rooms of the Royal Scottish Geographical Society at Edinburgh to advocate the use of the modern Norwegian methods of whaling in the South; but the proposal was not carried out, and no practical steps were taken.

Capt. Larsen afterwards became the commander of the *Antarctic*, the exploring vessel of Dr. O. Nordenskjöld's Swedish South Polar Expedition, 1901-3. The *Antarctic* was wrecked; and Capt. Larsen, on his return journey, found himself at Buenos Aires, where in 1904 he founded the Compania Argentina de Pesca, the first whaling company which undertook operations in the Far South. This company commenced work at South Georgia in 1905, while the South Shetland Islands were visited with the same object in 1906, and the South Orkney Islands in 1911. The operations have proved so successful that there are now numerous companies whaling at South Georgia and the South Shetlands, a large proportion being Norwegian. While the most successful whalers in the Greenland industry from the seventeenth to the nineteenth centuries were the British and the Dutch, the Norwegians have almost a monopoly of the art at the present time, and nearly all the skilled workers are of that nationality.

The older whalers hunted with hand-harpoons from small boats, provided with sails and oars, which were launched from the parent ship on sighting a whale. The objects of their chase were principally the Greenland whale, the Atlantic right whale, and the sperm whale; and they were unable to attack and capture the larger and swifter rorquals.

About 1865 the Norwegian whaling captain Svend Foyn invented the modern whaling-gun, which was fitted with an explosive tip and a barbed harpoon

*Discourse at the Royal Institution; reprinted from *Nature* (London).

carrying a strong rope. The explosion was regulated so as to occur immediately after the harpoon hit the whale, which is sometimes killed at once, and in any case is severely injured by a successful shot. The gun is carried in the bow of a steam-whaler, which chases the animal until a favorable opportunity for shooting occurs. These methods have revolutionized whaling, and there is now no whale which is too large to be captured.

In the prosperous days of the Greenland whale "fishery," 1437 whales were caught by seventy-six ships in 1814—an average of not quite twenty whales to each vessel—and this is mentioned by Scoresby (1820) as a specially good year. At the present day the number of whales caught by a single vessel during the whaling season of six months may rise to more than three hundred; and the total number caught off South Georgia and the South Shetlands together has exceeded 10,000 in one year. Bearing in mind the universal history of whaling in the past—a period of prosperity succeeded by a rapid decline and a final abandonment of the industry—the question arises whether there is not a serious danger that sub-Antarctic whaling will have a similar experience.

The question of the disappearance of the whales is not merely a sentimental one, though zoologists would naturally view their extermination with deep concern on scientific grounds. The plea for their preservation may be strengthened, however, by emphasizing the fact that they are of the highest economic importance. The baleen or whalebone of the right whales is a material of much practical utility for many purposes; but its importance is almost negligible compared with that of the oil which is derived from the blubber and other parts of whales. Whale-oil can be readily transformed into soap and glycerine, while it is possible to prepare from it a fat which is perfectly inodorous and is utilized in the manufacture of margarine. During the war it has been of vital importance. Enormous quantities of glycerine derived from it have been used for the manufacture of explosives, and it has been scarcely less important in its relation to the food supply. If whale-oil had not been obtainable, the glycerine which was essential for our national security must have been derived from other animal fats or from vegetable oils, and the shortage of fat required as food would have been very serious. After the oil has been extracted on the whaling grounds, the remainder of the carcass may be dried and ground down into "guano," which is valuable as a fertilizer for crops, and is also utilized for the preparation of cattle-foods. It is not always possible to carry out this part of the process, and an enormous waste of valuable material may result from this omission. Since it is well known that the flesh of Cetacea is fit for human food, it is by no means impossible that a part of the enormous quantity of meat which might be obtained from them may be so utilized in the future.

Although a few right whales and sperm whales are captured by the sub-Antarctic whalers, who occasionally kill some of the smaller Cetacea as well, the industry in these waters is almost entirely confined to three species of the larger whales. Of these the humpback rarely exceeds 55 feet in length, the fin whale is not much more than 85 feet, while the blue whale, probably the largest animal that has ever existed, is sometimes more than 100 feet long. In the first few years of sub-Antarctic whaling the humpback constituted nearly the whole catch, even more than 96 per cent. in 1910-11, when 5230 individuals of this species were captured off South Georgia in the six months of the principal whaling season. In 1912-13 the number of humpbacks caught in the same locality, in the corresponding six months, fell to 2,251 (about 53 per cent. of the total catch), and in 1913-14 it was reduced to 474 (about 18 per cent.). This diminution, which has persisted to the present time, has been due largely to a reduction of the number of humpbacks frequenting South Georgia; but it has been partly caused by an increase in the size of the whaling vessels and of the strength of the tackle employed, enabling the whalers to hunt the larger kinds, which naturally yield more oil and other products than the comparatively small humpback. The whaling industry thus depends at present almost entirely on the fin whale and the blue whale. It is noteworthy that the fin whale, of intermediate size, first rose to prominence on the decline of the humpback; but the gigantic blue whale has now surpassed it, and has become the favorite object of the whalers' pursuit. There is at present no certain evidence of the reduction in numbers of fin whales and blue whales.

In explaining the reduced number of humpbacks frequenting the whaling grounds, the whalers rely on the hypothesis that individuals of this species are of a timid nature, and are readily frightened away from a locality by pursuit. There is probably some truth in this view, but it is at least possible that the reduction is due to a diminution in number of the total stock of humpbacks. Whales are migratory animals, and their movements are almost certainly influenced by two causes: (1) the distribution of their food supply; (2) the position of their breeding grounds. The plankton organisms on which the whalebone whales subsist are present in vast quantities in polar waters during the summer, and the whales are accordingly found there at this period. Towards the end of the summer or the beginning of autumn most of them forsake high latitudes. The southern humpback executes extensive migrations northwards, along the coasts of the great southern continents, to the neighborhood of the equator, and even beyond it. It is in these warmer waters that it is known to breed, and it afterwards proceeds southwards in the ensuing spring. One of the most alarming facts about this species is that it has been extensively hunted along the coasts of Africa, South America, and elsewhere. Although it is not possible to assert positively that the South Georgia humpbacks are thus affected, there are strong reasons for believing that this is the case; and it would thus follow that this species is persecuted in sub-Antarctic waters during the summer, and further north during other parts of the year. Remembering that the old whalers reduced the Greenland whale almost to the point of extermination by the use of what may now be regarded as primitive methods, and that a similar fate has befallen the once-flourishing whaling industries of other localities, it thus appears that there are the most urgent reasons for seeking to afford some immediate measure of protection to this and other species of whales.

In devising methods for the protection of animals, the principle of saving them from being hunted during their breeding season has been found specially effective. It is very difficult to get complete information on this subject with regard to whales, but one of the ways in which a conclusion may be reached is the examination of fœtal records, a method which has already been adopted with some success by Guldberg and others. By the study of a relatively large mass of statistics which has been supplied to the British Museum (Natural History) by the whaling companies operating off South Georgia, I have found it possible to arrive at certain definite results which amplify or correct those of previous observers. These are specially clear in the case of the fin whale, which has provided the largest number of records. It is found that in a given month there is a particular length of fœtus which has the greatest frequency; that in the next month a greater length is most common; and so on for several succeeding months, after which the whaling season comes practically to an end, and the number of records is inadequate to give a normal result. Although there are certain irregularities needing explanation in the graphs constructed from the statistics, the general result has been arrived at that, in each of the three species principally hunted at South Georgia, pairing takes place with greatest frequency at a certain period of the year, and that a normal curve of pairing can be drawn. This result gives, in the main, a satisfactory explanation of the statistical records. The season when pairing is at its height falls in each case outside the period when whaling is actively carried on in the Far South; and the important conclusion is reached that if the whales are to be protected during their breeding season, it must probably be done in regions of the world farther north than South Georgia. The validity of the southern figures, which have, no doubt, been roughly recorded by the whalers, has been confirmed by obtaining corresponding results from the examination of the statistical fœtal records of northern whales.

It can scarcely be doubted that protective measures of some kind are urgently necessary now, or will at least become so in the near future; although it is by no means certain what form they should take. The British Government is, in some respects, in a specially favorable position with regard to this matter, since all the important whaling grounds of the sub-Antarctic region belong to the Dependencies of the Falkland Islands and lie in its jurisdiction. It is satisfactory to be able to conclude with the statement that the Government is fully alive to the necessity of taking steps before it is too late, and that an Inter-Departmental Committee is at present engaged, under the auspices of the Colonial Office, in framing a scheme for an expedition which is to investigate the whaling problem on the spot, with the view of obtaining information on which legislation may be based.

Detecting Over-Heated Bearings

CERTAIN double iodides of mercury with other metals are dimorphic and exhibit a more or less pronounced color change at the transition point. H. T. Pinnock has made a study of these in order to determine which compounds are most suitable for use as visible indicators of overheating in bearings and machinery.

The double iodide of silver and mercury, $AgI.HgI_2$, is a pale lemon yellow powder at ordinary temperatures, but changes to a vivid carmine at 90 to 100 deg. C., the change in both directions being fairly sharp. With copper mercuric iodide, $Cu_2I_2.2HgI_2$, the change from a vivid scarlet vermillion to a chocolate brown takes place at 60° to 70° C. It was found that a mixture of the two, consisting of 85 per cent. of the copper salt and 15 per cent. of the silver salt, was more sensitive and gave an exceedingly sharp transition from vermillion to almost black at 60° to 70° C.

For application to bearings, etc., these compounds are mixed with white shellac spirit varnish or, for more elevated temperatures, a medium such as is used in aluminium paints for steam pipes, in the proportion of 100 g.m. compound to 70 cu. cm. of medium. This paint is best applied as a bullseye or band on a zinc white background. After the paint is dry, it should be protected with a coat of colorless oilproof varnish.—*Chem. and Metall. Engineering.*

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